

Virginia Citizen Water Quality Monitoring Program **Methods Manual**

July 2003

Virginia Citizen Water Quality Monitoring Program Methods Manual

Prepared by:

**Virginia Citizen Water Quality Monitoring Program,
A cooperative effort of Alliance for the Chesapeake Bay, Virginia Department of
Conservation and Recreation, Virginia Department of Environmental Quality and Virginia
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Center for Marine Conservation & U. S. EPA. *Volunteer Estuary Monitoring: A Methods Manual, Second Edition*.

U. S. Environmental Protection Agency (USEPA), *Volunteer Lake Monitoring: A Methods Manual*. EPA 440/4-91-002.

U.S. EPA. 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA 841-B-97-003.

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Why is Volunteer Monitoring Important?

Hundreds of Virginians volunteer their time to monitor the quality of Virginia's waterways. These backyard scientists conduct many types of monitoring that vary in sophistication. Examples include: evaluating macroinvertebrate (mainly insect larvae) populations in streams, testing water samples for dissolved oxygen and pH, collecting water samples to be tested by a lab for bacteria and nutrients, and conducting habitat evaluations and stream walks. These volunteer monitors may not have degrees in science but they do have an interest in the quality of their environment. Spending time in the water gives them an opportunity to learn about water quality while collecting valuable data.

Volunteer monitors play an important role in protecting Virginia's natural resources. Although the Virginia Department of Environmental Quality (DEQ) has a large network of professional monitoring stations, DEQ cannot possibly monitor all the waterways in Virginia. Virginia has approximately 50,000 miles of streams and rivers, 2,500 square miles of estuaries, and 100 significant lakes (public water supply and/or > 100 acres) located in Virginia. Local governments may have their own monitoring programs, but those programs gain tremendously when supplemented with volunteer data. Volunteer data is used in a number of ways: to educate students and the community, to collect baseline information to prioritize monitoring needs and establish background conditions, to contribute to local land use decisions, to indicate unusual conditions, for special studies, and for statewide water quality assessment reports. The use of volunteer data as direct evidence in enforcement actions is not appropriate.

How Can You Become a Volunteer Monitor?

Becoming a volunteer monitor is easy. No special background is needed and any age group can participate. An existing organization working in your local watershed is a good place to start. Local organizations can usually provide the training and equipment needed. To find out if there is an existing program in your local watershed, contact the Virginia Citizen Water Quality Monitoring Program (Appendix 1). If there is not an existing program in your area, you may want to consider starting your own program. Any of the Virginia Citizen Water Quality Monitoring Program partners, Alliance for the Chesapeake Bay (ACB), Virginia Department of Conservation and Recreation (DCR), DEQ, and Virginia Save Our Streams Program of the VA Division of the Izaak Walton League of America (VA SOS) can provide assistance.

Virginia Citizen Water Quality Monitoring Program Contacts

- Alliance for the Chesapeake Bay
<http://www.AllianceChesBay.org>
- VA Department of Conservation & Recreation
<http://www.dcr.state.va.us>
- VA Department of Environmental Quality
<http://www.deq.state.va.us/cmonitor>
- VA Save Our Streams Program of the VA Division of the Izaak Walton League of America
<http://www.vasos.org>

Introduction to Citizen Water Quality Monitoring in Virginia

In 1998, Virginia took a major step toward developing the Virginia Citizen Water Quality Monitoring Program by creating the Citizen Monitoring Coordinator position at DEQ. This new position recognized years of effort made by local volunteer monitoring programs across the state to provide high quality data for resource managers. Since its inception, the program has encouraged citizen involvement in water quality issues and produced high quality monitoring data to meet state and local program needs. The 1999 Virginia General Assembly Session further supported the program by creating the Citizen Water Quality Monitoring Grant Program to provide funding for citizen monitoring activities.

ACB, DCR, DEQ, and VA SOS implement the program as a cooperative effort through a formal Letter of Agreement (LOA) signed on April 9, 2002 (Appendix 2). The LOA outlines the commitment of the signatories to developing a comprehensive volunteer monitoring program and the intended uses of water quality data collected by volunteers.



Letter of Agreement Signing Ceremony on April 9, 2002. Pictured are (left to right): Robert G. Burnley, Director, DEQ; Joseph H. Maroon, Director, DCR; David B. Bancroft, Executive Director, ACB; W. Tayloe Murphy, Jr., Virginia Secretary of Natural Resources; Jay Gilliam, Coordinator, VA SOS (*photo by Dawn Shank*).

The overall goals of the Virginia Citizen Water Quality Monitoring Program include:

- Supporting citizen monitoring efforts statewide: ACB, DCR, DEQ, and VA SOS provide a number of services to citizen monitoring groups, including coordination with DEQ monitoring efforts, technical assistance, assistance in locating funding, and training workshops.
- Promoting appropriate quality assurance and quality control: ACB, DCR, DEQ and VA SOS encourage use of appropriate protocols.
- Promoting the use of citizen water quality data in Virginia: Citizen monitoring data is promoted as described in the LOA and is actively sought for inclusion in the Water Quality Assessment Report prepared by DEQ under section 305(b) of the federal Clean Water Act for the U.S. Environmental Protection Agency (EPA) and the Virginia Water Quality Monitoring, Information and Restoration Act. This report assesses water quality data based on the ability of citizens to safely enjoy the designated uses of the

Commonwealth's waters as described in Virginia's water quality standards. Water quality data from a variety of sources are used for the assessments, including data collected by DEQ, other federal, state and local agencies, and volunteer monitoring organizations using DEQ-approved methods. For more information see <http://www.deq.state.va.us/water/305b.html>

- Promoting partnership and collaboration among citizen water quality monitoring efforts.

In 2002, the Virginia General Assembly passed legislation that established the Virginia Citizen Water Quality Monitoring Program in the *Code of Virginia* (Appendix 3). To implement this legislation, the program was modified. Given the substantial costs of laboratory analysis, citizen monitoring organizations that receive state funds to support these analytical costs must meet additional requirements to ensure that the data collected will be useful to DEQ. These programs are required to: (1) conduct the sample analysis at a laboratory with DEQ-approved standard operating procedures and quality assurance/quality control procedures; (2) not collect water samples during spill events or in areas where the data are not useful for water quality assessments, such as in mixing zones near discharge pipes and locations intensively monitored by DEQ; (3) collect water samples that are representative of the stream (usually collected mid-channel just below the water surface) in safe locations on public property or where landowner permission was obtained; (4) submit data electronically to DEQ in the format provided in Appendix 4, and (5) sign a Memorandum of Agreement (MOA) with DEQ. Appendix 5 is a boilerplate MOA between DEQ and a citizen monitoring organization. This boilerplate MOA provides the framework for a cooperative effort and will be customized as appropriate.

The Virginia Citizen Water Quality Monitoring Program supports Citizens for Water Quality (CWQ). CWQ is a statewide consortium of citizen groups, agency representatives, businesses, and individuals interested in preserving and enhancing water resources in Virginia. CWQ conducts an annual citizen monitoring summit and serves as an information exchange for individuals and organizations involved with volunteer water quality monitoring. CWQ hosts a list-serve (see Appendix 6 for information about this list-serve). The DEQ Citizen Monitoring Coordinator distributes meeting announcements and other information of interest to individuals and organizations on the CWQ mailing list.

Cooperative partnerships have enhanced relationships between state agencies and citizen monitoring organizations, which have improved the quality and quantity of citizen water quality data collected in Virginia. This foundation is expected to grow in the future.

Purpose of the Manual

Volunteer monitors are faced with a wide range of options. If you join an established program in your area, many decisions have already been made for you. If you are starting your own program, you will have many decisions to make. Since no program can measure everything all the time, you must make choices based upon what you are trying to learn about your watershed and your resources. This manual will help you make those choices when designing your program.

This manual provides guidance on the advantages and limitations of the more commonly used methods (protocols) for measuring water quality by volunteer monitoring programs and does not attempt to include every protocol for each parameter. Most of the methods listed are currently in use by citizen monitoring organizations throughout Virginia. The intent of this manual is not to limit the protocols used by organizations in Virginia, but to make the selection of protocols easier for newcomers to volunteer monitoring or for those expanding their volunteer monitoring programs.

In addition to this manual, there are many other resources on water quality monitoring (Appendix 7). This manual is specific to Virginia and is intended for use with other resources. Assistance in planning your program is available through the Virginia Citizen Water Quality Monitoring Program. If you are interested in DEQ using your data, you are encouraged to seek assistance from the DEQ Citizen Monitoring Coordinator. DEQ is most interested in data about conditions for which Virginia has water quality standards. Water quality standards describe water quality requirements necessary to meet and maintain uses such as swimming and other water-based recreation, public water supply, fish consumption, and the growth of aquatic life. To learn more about how water quality data is assessed for the Water Quality Assessment Report, please see the most current version of the Water Quality Assessment Guidance Manual (<http://www.deq.state.va.us/watguidance/wqam.html>).

**For More Information on Virginia's
Water Quality Standards**

- Virginia's Water Quality Standards
<http://www.deq.state.va.us/wqs/>

Organization of the Manual

This manual contains sections with chapters grouped by subject area. Section 1 contains Chapters 1-3 that describes planning your program before you begin monitoring and provides basic guidelines for every volunteer monitoring program. Section 2 contains chapters related to individual chemical monitoring parameters. Section 3 addresses specific biological measurements that volunteer monitoring programs may want to measure. Section 4 contains chapters related to physical measurements. The appendices contain additional useful information.

Each chapter devoted to a specific parameter (Chapters 4-15) contains a table describing methods for sampling that parameter (equipment suppliers for equipment can be found in Appendix 8). These tables do not include all available methods, but are meant to serve as references to methods used in Virginia. The tables list organizations using these methods (the contact information for these organizations can be found in Appendix 1) along with the monitoring level for each method. The level is based upon the appropriate uses for data collected using a particular method and the required quality assurance/quality control measures that are undertaken by the monitoring organization (Appendix 9 describes these monitoring levels). As more information becomes available on the methods, these levels are subject to change.

Section 1: Planning Before You Begin

Chapter 1: Planning Your Monitoring Program

Chapter 2: Developing a Quality Assurance Project Plan

Chapter 3: Before You Begin



Photo Courtesy of Virginia Save Our Streams

Chapter 1

Planning Your Monitoring Program

Planning Your Monitoring Program

Careful planning of your water quality monitoring program prior to recruiting volunteers and purchasing equipment is important because it can save considerable time and money. The Virginia Citizen Water Quality Monitoring Program provides technical assistance and training services to citizen monitoring organizations. When planning your program, you may want to consider creating a

committee of others interested in your program, such as data users, local college faculty, potential volunteers, local government staff, etc.

You can purchase a test kit and monitor water quality in your backyard for your own information. If you want your data to be useful to others, however, careful planning is important.

Appendix 10 contains worksheets that will be helpful in developing your monitoring program. Completion of the worksheets will help you focus your efforts and assist you in developing a program that collects useful data to meet the goals of your program.

Appendix 11 provides additional

technical information about planning a water quality monitoring program.

Joining an existing water quality monitoring program or working cooperatively with an established program is the easiest route for collecting water quality information as many of the decisions discussed in this chapter have already been made.

Your monitoring plan may change as your program evolves. For that reason, it is important to periodically update your monitoring plan. For example, program coordinators might find that a method is not producing high enough data quality, data collection is too labor-intensive or expensive, or additional parameters need to be monitored.

Step 1: What waterbody(ies) do you want to monitor and what is known about your watershed?

The first step is to determine what waterbody(ies) you want to monitor and if any monitoring data has been collected there previously. The Virginia Water Monitoring Council (VWMC) is comprised of organizations and agencies involved with water quality monitoring. Since the mission of the VWMC is to promote and facilitate coordination of water monitoring programs throughout Virginia, the VWMC has developed an online database that allows users to determine whether water quality data is or has been collected in a specific watershed. While this database is the most comprehensive source of water quality monitoring

Who is Monitoring in Your Watershed?

- Virginia Department of Environmental Quality
Water Quality Monitoring Database
<http://www.deq.state.va.us/water/monitoring.html>
- Virginia Water Monitoring Council
<http://www.vwrrc.vt.edu/vwmc/Survey.asp>

information, it may not include every source of data about your watershed. The Virginia Department of Environmental Quality's (DEQ) online water quality monitoring database allows you to view water quality monitoring data (both current and historical) collected by the agency. Local governments may also have data or other documents that describe local water quality issues.

Collecting information on the issues affecting your watershed is important in planning an effective monitoring program. Knowing the issues and what is already being monitored may help you to decide what to monitor and keep you from duplicating efforts. For example, a local college may be monitoring the same sites that you were planning to monitor. It is not practical for both entities to spend money and time collecting the same information at the same sites.

Step 2: Why are you monitoring?

Once you have determined what is known about your watershed, you should determine the overall goals for your monitoring program. This is the most important step in planning your program because other questions about the monitoring program (Steps 3-7) depend upon this initial step.

After you have researched the issues of the watershed, you should identify specific questions you want to answer and the information needed to address the issues. Can you collect volunteer data that can help fill in any data gaps?

Establishing Goals for Monitoring is Critical to Determine:

- How your data can be used and how good it needs to be
- Where you will monitor
- What parameters or conditions you will measure
- What methods you will use to monitor
- When you will monitor

Determining why you want to collect data is important in collecting useful information without wasting time and money. Common goals of citizen water quality monitoring programs include:

- Educating the local community about water quality issues to encourage protection of water quality
- Establishing baseline data where no other data exists
- Supplementing water quality data collected by agencies
- Documenting water quality changes over time (trends in water quality)
- Identifying potential water quality problems
- Providing a scientific basis for making decisions on watershed management
- Providing information to evaluate the effectiveness of best management practices
- Determining the impact of land use activity (urban, industrial, agricultural, etc.)

Step 3: How will your monitoring data be used and what level of data quality do your data users need?

Understanding how your data potentially will be used is essential to the program development. Partnering with potential data users during the planning process can improve the likelihood they will use your data. Some users, such as state agencies, will have more stringent requirements on the level of data quality needed and will require higher levels of quality assurance and quality control activities (activities used to assure data quality) than other data users. The range of uses of volunteer data uses is limited only by the imagination (Appendix 2).

Potential Data Users of Volunteer Data

- Environmental organizations
- State environmental agencies
- Local health departments
- Environmental consultants
- Universities/schools
- Local park staff
- Local planning and zoning agencies
- Soil and Water Conservation Districts
- U.S. Geological Survey
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service

Step 4: Where will you monitor?

Selecting representative sites is an important element in designing your monitoring program. Site locations will depend on the goal of the program. When selecting sites, you should consider the following questions:

- Is there a real need for data at the proposed sites?
- Do the proposed sites duplicate existing monitoring efforts by other organizations or agencies?
- Are the proposed sites in the main flow of the stream and representative of the stream (for smaller streams this is typically mid-channel and just below the water surface)? Representative also means that samples are not collected near a discharge pipe where the discharge mixes with the water in the stream.
- Are the proposed sites safe and easily accessible?
- Are the proposed sites on public property or can you obtain landowner permission?
- Is a proposed site above or below the confluence of two streams? If the site is below the confluence, the watersheds of both streams affect the water quality at the site.
- Can a representative water sample be collected during all tidal stages?

Selecting Sites

To make your program most effective, you may wish to discuss your potential site locations with the DEQ Citizen Monitoring Coordinator, who can provide assistance on site selection. It may be beneficial to discuss potential sites with intended local data users, including your local soil and water conservation district and your local government environmental staff.

Identifying Sites

Once you select the monitoring sites, you must be able to identify each site location. Your data is not useful without the exact monitoring location.

Determine latitude and longitude using a GPS unit in the field or pinpointing the site on a U. S. Geological Survey (USGS) 7.5 minute series topographic map (1:24,000 scale).

In addition to latitude and longitude, a brief description of the site location (i.e. north side of Rt. 0 bridge crossing Deer Creek) is useful. A narrative description provides a way for someone to quickly identify the site location without plotting the latitude and longitude.

Obtaining USGS Topographic Maps

- Use the maps on <http://www.topozone.com> at no cost (see Appendix 12 for instructions for using Topozone).
- The USGS Earth Science Information Center (ESIC) provides a catalog of available maps and a brochure on how to use topographic maps. Contact the main ESIC office at 888-ASK-USGS or at <http://ask.usgs.gov>.
- Commercial distributors include sporting goods stores and engineering/architectural suppliers

Assigning Site Numbers

You should develop a systematic approach to assigning site identification numbers. Identifying each site by an assigned unique number provides greater consistency than using a site name, which may be modified easily by newcomers to your program.

Sampling Depth

In addition to geographic location, you need to determine the depth you plan to sample in the water column. For most volunteer programs, just below the surface will be sufficient for most parameters. DEQ surface water samples are typically 0.3 meters (1 foot). If you are planning to monitor a lake or deep estuarine waters, this is a critical question, particularly for dissolved oxygen monitoring. Dissolved oxygen in lakes and the Chesapeake Bay can vary greatly with depth (this vertical stratification is discussed further in Chapter 4). Sampling at greater depths (greater than 1 foot or 0.3 meters) may require special water sampling devices (see Chapter 4).

Step 5: What parameters or conditions will you measure?

Our waterways are complicated systems. Determining what to monitor will depend on the goals of your program, the intended use of the data, the needs of the data users, and the resources of your volunteer monitoring program. If, for example, your goal is to provide baseline data that will be useful to state water quality agencies, you should consult those agencies to determine which parameters have state water quality standards and which they consider of greatest value.

DEQ is most concerned with parameters for which Virginia has water quality standards (please refer to the Introduction of this manual). Costs of test kits or meters, available laboratory facilities, assistance from state or university advisors and/or laboratories, and the abilities and desires of volunteers will also have an impact on the choice of parameters to be monitored. Table 2-1 lists some water quality parameters that are commonly monitored by volunteer monitoring programs in Virginia. More detailed information can be found in Chapters 4-17.

Table 2-1. Common Water Quality Parameters

Parameter	Virginia Water Quality Standard	Importance
Dissolved Oxygen	Yes	Essential for aquatic organisms.
pH	Yes	Affects chemical and biological processes; organisms can only survive in specific range.
Nitrogen	Standard for nitrate in public drinking water supplies; others to be developed.	Essential for plant growth; necessary for metabolism and growth of aquatic organisms.
Phosphorus	Screening value for total phosphorus; standard to be developed.	Essential for plant growth; necessary for metabolism and growth of aquatic organisms.
Benthic Macroinvertebrates	Narrative standard	Good indicators of water quality.
Bacteria	Yes	Indicator of fecal contamination; can cause illness.
Chlorophyll <i>a</i>	Screening value for Chlorophyll <i>a</i>	Estimates the abundance of algae.
Submerged Aquatic Vegetation (SAV)	No	Food and habitat for aquatic organisms.
Temperature	Yes	Affects chemical and biological processes.
Turbidity/Transparency or Total Solids	No	Indicators of runoff effects; affect sunlight reaching SAV.
Salinity	No	Affect the distribution of plants and animals in estuarine environments.
Conductivity	No	Useful measure of general water quality. Significant changes may indicate a discharge or another source of pollution.

Step 6: What methods will you use to monitor?

For most parameters, there are a variety of monitoring methods available with varying complexity and levels of data quality. You should select methods based upon cost and the quality of data necessary to meet the goals of the program and the intended data use. For example, data intended for water quality assessment use by DEQ must be collected using DEQ-approved methods and requires a higher level of data quality than data used to screen for potential problems (Appendix 9). You can, for many parameters, begin monitoring using less sophisticated equipment and upgrade your methods as resources allow. Partnering with colleges and universities is beneficial since they generally have technical knowledge and often have equipment available (please refer to the Winter 2003 edition of *The Volunteer Monitor* newsletter available at <http://www.epa.gov/owow/monitoring/volunteer/winter2003/volmon15.pdf>).

Meters may be used to measure many water quality parameters such as temperature, dissolved oxygen, pH, and conductivity/salinity. Although meters are quick to use in the field, they are more expensive than test kits and require calibration and maintenance to ensure accuracy. Sophisticated equipment will not provide better data if it is not properly used. Field test kits for the same parameters may be less expensive but may be unacceptable to some data users. Please refer to Chapters 4-17 for discussions of appropriate methods for commonly measured parameters.

When choosing a method, you should consider the detection limit (the smallest concentration of a parameter that can be detected) and the range. When selecting a test kit or other method, it is helpful to first determine the average value for the parameter in your stream so that you can select an appropriate method. For example, a test kit whose detection limit is 0.2 mg/l for total phosphorus will not be very useful if the typical total phosphorus concentrations are 0.04 mg/l. The importance of the detection limit depends heavily on the intended use of the data. While results from the total phosphorus kit mentioned above might not have much use from an agency perspective, it can detect when total phosphorus levels are elevated.

Step 7: When will you monitor?

In deciding when to monitor, you should consider several time scales: time of year, monitoring frequency, time of day, and sample holding time.

Time of Year

Aquatic ecosystems change seasonally and the data usually reflects these changes. During wet weather, more runoff carrying bacteria, nutrients, and pollutants enter waterways. Therefore, higher levels of these parameters generally are found during rainy seasons. Seasonal temperature changes greatly influence dissolved oxygen levels as colder water can hold more dissolved oxygen than warmer water. Due to seasonal variability, water quality monitoring events should be distributed throughout the year.

Monitoring Frequency

Ultimately, sampling frequency depends on the goals of the program, financial resources, and volunteer resources. For the purpose of DEQ's water quality assessment, sampling events should be conducted in such a manner that each sampling event represents an "independent" measure of water quality. Monitoring events are not considered independent if they are not sufficiently separated in time. Although the interval between sampling events that is necessary to insure independence of measurements is parameter-specific, a longer interval ensures the independence of the observations. Water quality monitoring events should be distributed evenly throughout the year on a certain interval (such as weekly, biweekly, monthly, bimonthly, or quarterly). When determining the sampling interval, you should keep in mind that one or two sampling events are generally not very useful in determining the water quality at a station. Larger data sets can be used to discriminate among rare, sporadic, frequently recurring, or continuous water quality issues.

Sampling several times during the year is sufficient for benthic macroinvertebrates since they indicate conditions over a long period of time. The VA Save Our Streams Program (VA SOS), for example, trains volunteers to sample macroinvertebrates once each season. Sampling of bacteria in a popular swimming area may be performed more frequently during the summer if the goal of the program is to determine if the water quality is safe for swimming.

Time of Day

Since some parameters (dissolved oxygen, pH, water temperature) fluctuate depending upon the time of day they are measured, it may be helpful to select a consistent sampling time for a site. Volunteers cannot be expected to always sample at the same time of day, but some consistency can help reduce the daily variability in the data. More data collected at a site over time will better identify some of this daily variability.

Temperature, dissolved oxygen, and pH can fluctuate naturally as the sun rises and aquatic plants undergo photosynthesis. Dissolved oxygen levels, for example, are generally lowest at sunrise and highest in the afternoon as aquatic plants consume oxygen during the night and release oxygen as a byproduct of photosynthesis during the day.

If you are monitoring tidal waters, tidal action affects the representative natural conditions of the water body. Most volunteer programs do not monitor based upon tidal stage because it is not reasonable for volunteers to adapt to the continuous time changes of tidal stages. If possible, it is preferable to collect samples on the ebb or slack tide.

Holding Time of Samples

The maximum time that samples can be held before testing (holding time) should also be considered. Delivering samples to a lab on a Friday afternoon is not reasonable if the lab is closed on weekends and the samples have a short holding time.

Step 8: How will you manage your data and present your monitoring results?

You should have a clear plan for handling the data collected. Someone must check field and lab data sheets while screening for outliers (results that differ significantly from past or expected results), enter the data into an electronic format, and check for data entry errors. Where will the data sheets be stored? You may need to develop or adapt an electronic database or spreadsheet to store and manipulate the data so that it will be more readily available for data users. DEQ has developed a format for submitting data to the agency for the 305(b) Water Quality Assessment Report that you may want to adapt for your own use (Appendix 4). The U. S. Environmental Protection Agency (EPA) maintains a national database for water quality, biological, and physical data called STORET. STORET permits national data analyses and allows the sharing of data among organizations. Specific quality control measures are required for any data entered into the database. For more information, please see <http://www.epa.gov/storet/>.

In creating a database, having a plan for analyzing and communicating the data to the public, to data users, and to the volunteers is useful. Raw data may have limited meaning to the public without some summarization and interpretation of the results. The volunteers will more than likely want to know “what the data means.”

Step 9: How will the program ensure that data are credible?

Making decisions and answering the questions addressed in Steps 1-8 are the first steps to ensuring that the data collected by your program is credible. The level of data quality needed is dependent upon the goals of your program and the intended uses of the data. If the goal of your program is education, then data credibility may not be a high priority. If your program is designed to collect data that can be used in making management decisions or to assess water quality, data credibility is very important.

Potential data users may be skeptical of volunteer data and have doubts about the ability of the program to collect accurate results. A written plan, known as a Quality Assurance Project Plan (QAPP), is key to overcoming this skepticism. The QAPP documents all aspects of your program, including the training and retraining of volunteers, the methods used to collect the data, data management, data reporting, equipment checks and project goals. Without such documentation, the data may not be used with confidence. The QAPP is also important for educating future volunteers and data users about every aspect of the program.

Please see Chapter 2 for a detailed description of developing a QAPP.

Chapter 2

Developing a Quality Assurance Project Plan

What is a Quality Assurance Project Plan (QAPP)?

The quality assurance project plan is a written document that describes all aspects of your program and includes the detailed quality assurance and quality control activities that will be used to assure data quality. The QAPP describes the organization of the program and includes the standard operating procedures (SOPs) for sample collection in the field and lab analysis. The monitoring plan you developed in Chapter 1 is the foundation for the QAPP. If you have carefully completed the worksheets in Appendix 10, you already have most of the information needed for your QAPP!

Quality assurance (QA) and quality control (QC) are those activities you undertake to demonstrate the accuracy (how close to the true result you are) and precision (how reproducible the results are) of your monitoring. QA generally refers to a broad plan for maintaining quality in all aspects of a program, including quality control measures, sample collection, sample analysis, data management, documentation, etc. QC consists of the steps, including measurements, calibrations, etc., you will take to assure the quality of specific sampling and analytical procedures. The Virginia Water Monitoring Council has developed a handout explaining basic QA/QC concepts (Appendix 13).

What Does a QAPP Include?

- Who does what?
- Project goals
- How good does the data need to be to meet goals?
- Training of volunteers
- Documentation (field sheets, lab sheets)
- Sample Design: who, what, when, where, how
- Methods used (field SOPs)
- Sample handling and analysis (lab SOPs)
- QC requirements
- Equipment calibration, checks, and maintenance
- Data management, reporting, and review

Why is a Quality Assurance Project Plan Important?

If the goal of your volunteer monitoring program is to collect data that can be used for management decisions, your data users may require a QAPP or at a minimum documentation of your methods. The QAPP provides the documentation that assures the quality of the data to your data users. The burden of proving the data quality is on your organization.

Although the development of a QAPP may appear to be a difficult process, it will be well worth the effort to see your data used in a meaningful way. Seeing the program's data used may provide additional motivation for retaining and recruiting volunteers who want their efforts to be worthwhile. A written QAPP is also important for educating future volunteers, project managers, and data users about the program and how the program is organized.

For the Department of Environmental Quality (DEQ) to use volunteer data for 305 (b) water quality assessment, the data must be collected under a DEQ-approved QAPP using QA/QC measures acceptable to DEQ. The U. S. Environmental Protection Agency (EPA) requires that any monitoring program sponsored by EPA through grants, contracts, or other formal agreements carry out a quality assurance/quality control program and develop a quality assurance project plan.

How Do You Develop a Quality Assurance Project Plan?

Developing a QAPP is a dynamic process that should involve consulting the data users for their requirements. Seeking advice from other organizations using similar methods also can be helpful. The DEQ Citizen Monitoring Coordinator is available to provide assistance with QAPP development. Any program seeking DEQ approval of a QAPP should submit the plan to the DEQ Citizen Monitoring Coordinator.

DEQ recommends that all citizen water quality monitoring QAPPs follow the format outlined in *The Volunteer Monitor's Guide to Quality Assurance Project Plans* developed by EPA. This guide is available at <http://www.epa.gov/owow/monitoring/volunteer/qappcovr.htm>. Appendix 14 is a QAPP template from the EPA guide that you can use for developing your QAPP.

Chapter 3

Before You Begin

Preparation for Monitoring

Volunteers should check their equipment, test kits, and reagents (chemicals) to ensure that they are in proper condition prior to sampling. Data sheets and labels for lab samples can be prepared at home prior to monitoring to save time and minimize errors in the field.

Reused sample containers and glassware should be cleaned and rinsed after each sampling event. All reagents should be stored tightly capped away from heat, sunlight, and extreme cold. All reagents should be stored out of the reach of children and pets.

Signs of Degraded Reagents

- Color has changed
- Reagent has floating particles or solids forming
- Crust has formed around lid
- Past expiration date (Appendix 15 gives instructions on determining the expiration date of some commonly used test kit reagents)

Safety

Safety is the most important element of any volunteer monitoring program. **No data is more important than safety! Safety always comes before data collection.** If a site appears severely polluted or there is an urgent problem (such as fish kill, leaking drum, or oil spill), volunteers should **not** sample and immediately report the pollution event to the Virginia Department of Environmental Quality (DEQ) for investigation.

Training for all volunteers should include a safety component. All volunteer monitors are encouraged to sample in teams or with partners and to inform someone where they are going and when they plan to return. All monitoring stations should be safe for volunteers to access and perform their sampling. All volunteers should be instructed to take additional safety precautions in high water conditions. Additional safety rules for volunteer monitors can be found in the box on the next page.

Reporting an Urgent Pollution Event

- During normal work hours, call the appropriate DEQ Regional Office. A map of DEQ Regional Offices and phone numbers to report pollution incidents can be found at <http://www.deq.state.va.us/prep/contacts.html>.
- On nights, holidays, and weekends call the Department of Emergency Management's (DEM) 24-hour reporting number.
In-state calls: 800-468-8892.
Out-of-state calls: 804-674-2400
- Assemble the following information about the pollution event (if known): location of the pollution event (so that staff can investigate), when was the pollution event observed (report as soon as possible), what is the observed problem and who is causing the problem.

Safety Rules for Volunteer Monitors

- Watch weather reports prior to going into the field.
- Carry first aid kit and water.
- Dress properly for the weather. Don't forget to wear blaze orange during hunting season! The Department of Conservation and Recreation (DCR) has a limited number of orange vests available through the Adopt-A-Stream Program at adoptastream@dcr.state.va.us.
- Sample in teams or with partners.
- Inform someone where you are going and when you plan to return.
- All monitoring stations should be safe for volunteers to access and perform their sampling.
- Inform sampling team members of relevant health information in case of emergency.
- If you do not feel comfortable with the monitoring site or your surroundings, leave the site.
- If the site appears severely polluted, report immediately.
- If you drive to site, park in a safe location.
- Do not cross private property without permission.
- Watch out for poisonous plants and wildlife. Dress appropriately for protection against ticks.
- Be careful on bridges, stream banks, boats, docks, and when wading. If you monitor from a boat, abide by all boating regulations (see the Virginia Department of Game and Inland Fisheries website at <http://www.dgif.state.va.us/boating>).
- Do not wade in fast moving or high water.
- Use antibacterial soap after monitoring and do not eat until you have washed your hands.
- Avoid contact between chemicals and skin, eyes, or mouth. Wearing gloves is recommended.
- Properly store all chemicals away from children and pets, while avoiding extreme temperature fluctuations and direct sunlight.
- Properly clean up and dispose of any spills of chemicals.
- Properly dispose of all wastes from test kits.

Collecting Water Samples

Sections 2-4 of this manual discuss different types of sampling methods for various parameters in more detail. There are some general rules of thumb that you can apply for collecting water samples. Water samples should be collected in the main flow representative of the stream you are monitoring (for small streams, this is usually mid-channel). Please see the box on page 3-4 for more information.

Samples being transported to a lab should be properly labeled. It is recommended that lab sample labels include the name of the collector, site number, date, and time in case the lab has any questions about the sample. Samples being transported should be properly preserved (usually in a cooler with ice – blue ice packs are not recommended).

Using a Meter

- When using a meter to measure stream conditions, it is recommended that you place the meter directly in the stream or lower it from a bridge (please see the box on page 3-4 for more information). An alternate method is to collect the water sample in a bucket and use the meter to immediately take measurements in the bucket.
- Always be careful that the probes are protected from impact and are placed in an area representative of the stream.
- Meter probes should be lowered to about 0.3 meters (1 foot) below the surface of the water.

Samples Collected Directly from Stream with Sample Containers

- If possible, collecting water samples directly from the stream is preferable to using a bucket as it reduces the possibility of contamination and carryover from previous sampling, especially for bacterial sampling. If wading is not possible for collecting bacterial samples, consider using an extension pole for your bacteria sample bottle.
- When wading, approach sampling location from downstream.
- While facing upstream, thoroughly rinse sample bottles with stream water (do **not** rinse sample containers used for bacterial samples). If rinsing containers with sample water, discard rinse water downstream of sample site or on the stream bank.
- Collect samples while facing upstream and avoid disturbing sediment.

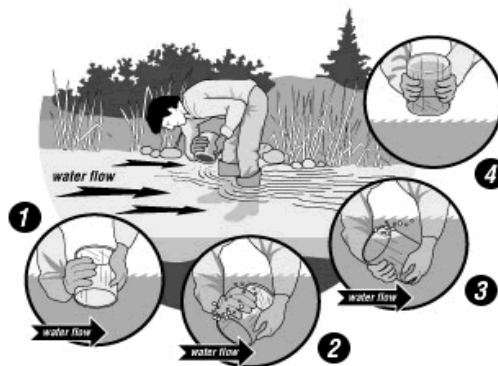


Figure 3-1. Collecting a water sample (from *Volunteer Estuary Monitoring: A Methods Manual, Second Edition*).

Samples Collected Directly from Stream with a Bucket

- Gently toss or lower bucket into an area representative of the stream (please see box on page 3-4 for more information on collecting samples from a bridge or by wading). If you are collecting sample water for dissolved oxygen analysis, be especially gentle. Splashing the water in your bucket can aerate your sample and alter your results.

- Rinse the bucket thoroughly with sample water before collecting sample water. Do **not** rinse the bucket if you are collecting water for bacterial sampling. Discard rinse water downstream of sample site or on the stream bank.

Collecting Water Samples

- Samples should be collected in the main flow representative of the stream you are monitoring (for small streams, this is usually mid-channel) just below the water surface, about 0.3 meters (1 foot) deep.
- Samples should not be collected in stagnant water or next to the stream bank.
- Sample collection is not recommended in the immediate mixing zone of a discharge. Only samples representative of the stream (once effluent is well mixed with the stream flow) can be used by DEQ for water quality assessments.
- If you collect samples by wading, you should be careful and always approach the sampling location from downstream trying to disturb bottom sediment as little as possible. You should always face upstream to collect your samples or take measurements.
- If samples are collected from a bridge, you should collect from the upstream side of the bridge if there are no cables present. If cables are present, use the downstream side of the bridge.

Section 2: Chemical Monitoring

Chapter 4: Dissolved Oxygen

Chapter 5: pH

Chapter 6: Nutrients



Photos by Betsy Briggs at Lake Anna Photography and Alliance for the Chesapeake Bay

Chapter 4

Dissolved Oxygen

What is Dissolved Oxygen?

Oxygen is found in aquatic systems as dissolved oxygen (DO) which enters the systems from the atmosphere and from photosynthesis of aquatic plants (Figure 4-1). Currents and waves help introduce oxygen into the aquatic system due to more water being in contact with the atmosphere and better mixing of surface and deeper waters.

Why Monitor Oxygen?

Dissolved oxygen is one of the most important measures of water quality. An aquatic system with low levels of oxygen cannot support healthy populations of animal or plant life. If more oxygen is being used than is being introduced, organisms may weaken, move away, or die. Aquatic animals and plants use oxygen for respiration. Oxygen is also removed from the aquatic system through decomposition of organic material. Excessive nutrient levels from runoff, failing septic systems, or wastewater from sewage treatment plants can contribute to low dissolved oxygen levels by causing abundant growths of phytoplankton (microscopic plants and algae) called blooms. Living phytoplankton may deplete oxygen levels during the night and as the phytoplankton die, decomposition of the organic material by bacteria consumes oxygen.

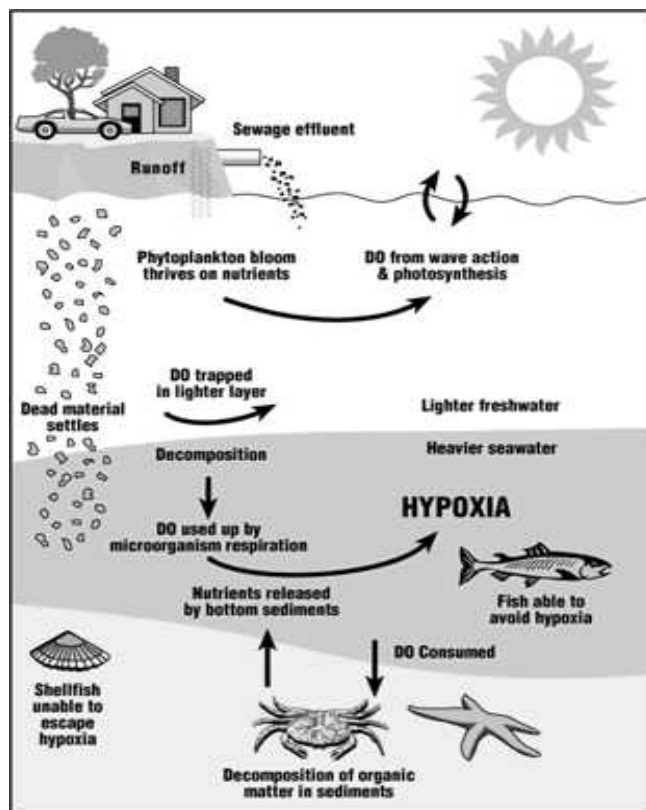


Figure 4-1. Processes affecting dissolved oxygen levels (from *Volunteer Estuary Monitoring: A Methods Manual, Second Edition*).

What Do Your Dissolved Oxygen Results Mean?

Dissolved oxygen (DO) is measured in mg/l (which is equivalent to parts per million or ppm). Aquatic organisms need a certain amount of dissolved oxygen in order to survive. The effects of low dissolved oxygen concentrations on aquatic organisms can be found in Table 4-1. Table 4-2 summarizes the water quality standards for dissolved oxygen in Virginia.

Table 4-1. Effects of Dissolved Oxygen on Aquatic Life

Levels of Dissolved Oxygen			
> 5 mg/l	Between 3 – 5 mg/l	<3 mg/l – Hypoxia Occurs (low dissolved oxygen levels)	<0.5 mg/l - Anoxia Occurs (lack of dissolved oxygen)
Level needed to support most aquatic life.	Aquatic organisms may become stressed.	Mobile organisms will move to areas of higher dissolved oxygen and immobile species may die.	Waters cannot support most aquatic life.

Table 4-2. Virginia Water Quality Standards for Dissolved Oxygen

	Most Waters	Stockable Trout Waters	Natural Trout Waters
Concentration of Dissolved Oxygen	Minimum 4 mg/l	Minimum 5 mg/l	Minimum 6 mg/l

Dissolved oxygen concentrations are affected by a number of variables such as time of day, depth, temperature, and salinity. Typically, DO concentrations of surface samples are highest around mid-day due to photosynthetic activity of aquatic plants. During the night, DO concentrations decline as DO is consumed through respiration while photosynthesis is halted due to the lack of sunlight. Therefore, DO levels are typically lowest in the early morning. Salt water cannot hold as much DO as fresh water (Figure 4-1). Lower DO concentrations are expected during the summer, since warm water cannot hold as much DO as cold water.

DO levels in lakes and estuaries can vary greatly with depth. During the summer months, vertical stratification (where warmer water is above colder water), can keep dissolved oxygen from reaching deeper waters. The deeper waters may maintain a low DO level until mixing occurs during storms or change of seasons.

The potential DO level, or DO saturation, is the maximum dissolved oxygen level possible under factors, such as temperature and salinity, that affect DO. Appendix 16 summarizes DO saturation levels at sea level at varying salinities and water temperatures. Percent saturation is the amount of oxygen in the water relative to the potential DO level. Percent saturation can be determined as follows:

$$\% \text{ Saturation} = \frac{\text{measured DO}}{\text{DO saturation (from Appendix 16)}} \times 100$$

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, further considerations specific to monitoring for dissolved oxygen are discussed below.

When to Sample

Since DO fluctuates seasonally, it is best to sample DO throughout the year to obtain a more complete picture of water quality. If this is not possible, then sampling early spring through late fall may be preferred since critical DO levels are most common during warmer periods of the year. Since dissolved oxygen may fluctuate throughout the day, you may wish to sample about the same time of day so that your data does not show these fluctuations. This may be of particular interest if you are monitoring estuarine or lake waters and plan to track trends in DO levels.

Where to Sample

As described earlier, vertical stratification can affect DO levels at different depths. Since dissolved oxygen levels vary depending upon the depth, especially in the warmer months, volunteer monitoring programs may decide to measure DO at varying depths. This may be of particular interest if you are planning to monitor lakes or estuarine waters. Several water samplers designed to collect samples at different depths are shown in Figure 4-2. Meters attached to long cables can be used to collect profile data directly.

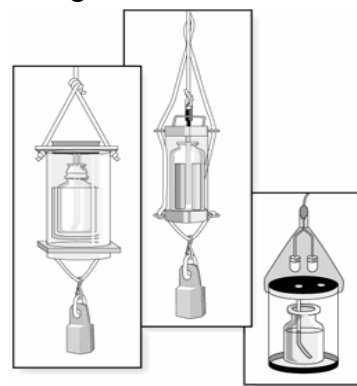


Figure 4-2. Dissolved oxygen samplers (from *Volunteer Estuary Monitoring: A Methods Manual*, Second Edition).

Choosing a Method

Dissolved oxygen can be easily and accurately measured using field test kits or meters. If using a meter, DO must be measured in the field. Some field test kits also require DO to be measured in the field, while others that are based on the Winkler titration method allow you to fix the water sample immediately upon collection and complete the analysis in a more desirable location within a few hours. The fixed samples must be stored in the dark without extreme temperature fluctuations.

Test Kits

Test kits may be more cost-effective than meters, but they do require replacement reagents once reagents expire or are used. Test kits also require proper storage, safety precautions, and proper disposal of waste. Monitors must follow protocols closely to ensure accurate results.

Test kits with increments greater than 0.2 mg/l or those not based upon a Winkler titration have limited uses, such as for educational purposes or to screen for potential problems. Winkler titration field test kits that measure DO in increments of 0.2 mg/l or less are acceptable for Department of Environmental Quality (DEQ) water quality assessments if the Quality Assurance Project Plan (QAPP) is approved by DEQ. Recommended quality assurance/quality control (QA/QC) measures include collecting and testing two water samples simultaneously to verify that the sampling is being done correctly. The difference between the two samples should be no more than ± 0.6 mg/l.



Volunteer measuring dissolved oxygen using a test kit (*photo courtesy of Alliance for the Chesapeake Bay*).

Colorimeters

This instrument measures DO concentrations based upon the absorption spectrum. A colorimeter requires proper maintenance and calibration. The data collected with this instrument are not acceptable for use by DEQ for water quality assessments since this method has not been compared to other approved methods.

Meters

While meters are more expensive than test kits, they can provide accurate results and may allow collection of several parameters with one instrument. Data collected with meters are acceptable for DEQ water quality assessments if the QAPP is approved by DEQ. When choosing a meter, one that compensates for barometric pressure and includes a stirrer (the stirrer maintains a consistent flow over the probe's sensor) is recommended. In areas of good flow, a stirrer may not be necessary as long as the probe is gently swirled in the water and the flow is at least 1 foot per second. The results of the DO reading can be altered depending upon how fast the probe is swirled.

A meter must be calibrated at the beginning of each sampling day. The calibration results should be acceptable when compared to the chart of percent saturation in Appendix 16. If the results are not within ± 0.5 mg/l of the percent saturation chart, the data collected with the meter should be flagged.

Additionally, the calibration should be confirmed at the end of the sampling day (this is referred to as a "post check") to determine if the meter has drifted throughout the sampling day. The post check should be conducted similar to the calibration without pressing the calibration button. The value obtained should also be compared to Appendix 16 in the same manner as described in the previous paragraph.

Since a meter can sometimes malfunction, you should confirm the meter measurements with an approved method (a Winkler titration test kit with increments no greater than 0.2 mg/l will suffice) once for every 20 sampling events (this is referred to as a QA/QC check). The meter should read within ± 0.5 mg/l of the approved method. If the results are not within this range, the data collected with the meter should be flagged. All calibration, post check, and QA/QC data should be maintained.

Summary of Dissolved Oxygen Monitoring Methods

Method (Vendor and Catalogue #)	Approximate Cost	Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)	Organizations Using Method
Winkler Titration Test Kit (Hach #1469-00)	\$47.75 (100 tests)	I	None known
Winkler Titration Test Kit (LaMotte #7414 [acid powder] or #5860 [liquid acid])	\$40.95 (50 tests)	I, II, or III	<ul style="list-style-type: none"> - Alliance for the Chesapeake Bay and affiliate organizations - Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University) - Lake Anna Civic Association - Upper Rappahannock Watershed Stream Monitoring Program
Colorimeter	\$150-\$1000	I	<ul style="list-style-type: none"> - Friends of Powhatan Creek Watershed
Meters (a multi-parameter meter is more cost-effective than a single parameter meter)	\$500-\$1000 (DO only) \$900-\$5,000 (multi-parameter)	I, II, or III	<ul style="list-style-type: none"> - Friends of the Shenandoah River and affiliate organizations - Loudoun Wildlife Conservancy - Piedmont Region TMDL Initiative

Chapter 5

pH

What is pH?

pH is a term used to indicate the acidity or alkalinity of a solution as ranked on a scale from 0 to 14. Acidity increases as the pH decreases. The pH scale measures the concentration of hydrogen (H^+) and hydroxide (OH^-) ions, which make up water ($H^+ + OH^- = H_2O$). When both types ions are in equal concentration, the pH is 7.0 or neutral. Below 7.0, the water is acidic (there are more hydrogen ions than hydroxide ions). When the pH is above 7.0, the water is alkaline, or basic (there are more hydroxide ions than hydrogen ions).

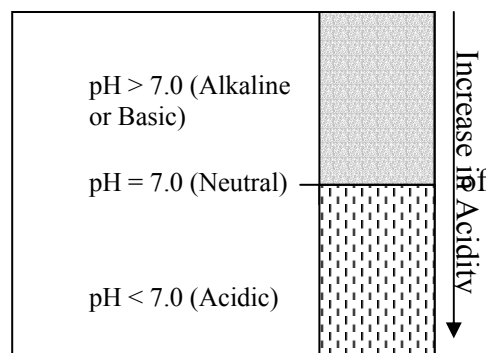


Figure 5-1. pH scale

Why Monitor pH?

pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. Most aquatic organisms prefer a pH range between 6.5 and 8. A pH value outside this range reduces the diversity in the waterway because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to dissolve and become more "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout. Changes in acidity can be caused by atmospheric deposition (including acid rain), weathering of surrounding rock, certain wastewater discharges, and the decomposition of plants and animals.

What Do Your pH Results Mean?

The water quality standard in Virginia defines acceptable pH as being between 6 and 9. pH values above or below this range indicate a violation of our state's water quality standards.

Since the pH scale is logarithmic, a drop in the pH by 1.0 unit is equivalent to a 10-fold increase in acidity. For example, a water sample with a pH of 5.0 is 10 times more acidic than one with a pH of 6.0, and a pH of 4.0 is 100 times more acidic than a pH of 6.0. Changes in pH of just one or two units can be very stressful to aquatic organisms.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, further considerations specific to monitoring for pH are discussed below.

When to Sample

Since pH fluctuates daily and seasonally, it is best to sample pH throughout the year to obtain a more complete picture of water quality. Because pH, like dissolved oxygen, may fluctuate throughout the day due to photosynthesis, you may wish to sample about the same time of day so as not to confuse daily fluctuations with pollution events. pH is increased by photosynthetic activity, which results in daily fluctuations, especially on sunny, warm days. This is of particular interest if you plan to track trends in pH levels.

Choosing a Method

pH is easily measured and must be measured in the field within 30 minutes (immediately is preferable) of collection of the water sample.

Test Kits

Test kits may be more cost-effective than meters, but they require replacement reagents once reagents expire or are used. Test kits also require proper storage, safety precautions, and proper disposal of waste. Monitors must follow protocols closely to ensure accurate results. pH test kits are cheap, safe and easy to use.

If you plan on using a field test kit with a limited pH range, you should first determine the average pH for your stream in order to select the correct range for your test kit. You can determine the average pH of your stream by either testing the stream with a wide range test kit (typically measures pH values from about 3-10) or locating existing pH data.



Volunteer measuring pH using a test kit
(photo courtesy of Alliance for the Chesapeake Bay).

Since many citizen monitoring programs in Virginia use the LaMotte pH (liquid) test kits, the Department of Environmental Quality (DEQ) conducted a comparison study between these test kits and a reliable meter. These test kits were found to be useful for DEQ water quality assessments if the Quality Assurance Project Plan (QAPP) is approved by DEQ. However, DEQ does not plan to list waters as impaired for pH based solely on these tests since the color determinations may have a degree of subjectivity.

Colorimeters

This instrument measures pH based upon the absorption spectrum. This instrument requires proper maintenance and calibration. The data collected with this instrument are not acceptable for use by DEQ since this method has not been compared to other approved methods.

Meters

While meters are more expensive than test kits, they can provide accurate results and may allow collection of several parameters with one instrument. Data collected with meters are acceptable for use by DEQ for water quality assessments if the QAPP is approved by DEQ.

A meter must have the ability for calibrations at a minimum of 2 well-separated pH values (2-point calibration) to meet DEQ's QA/QC requirements. pH meters should be calibrated with at least 2 standard pH buffers (solutions of known pH values) for the range where pH values usually occur. If the pH value is usually below 7, then calibration should be done with standard pH buffers 4 and 7. If pH value is usually above 7, then calibration should be done with buffers 7 and 10. Meters must be calibrated at the beginning of the sampling day.

A post check must be conducted at the end of the day to determine if the meter has drifted throughout the sampling day. A post check means that you take pH readings for the same buffers you used at the beginning of the sampling day (this is not a calibration). The results for each buffer must be within ± 0.2 units of the buffer value. If the results are not within this range, the data collected with that meter should be flagged. All calibration data should be maintained.

Summary of pH Monitoring Methods

Method (Vendor and Catalogue #)	Approximate Cost	Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)	Organizations Using Method
Wide Range (3.0 – 10.0) Field Test Kit (LaMotte # 2117)	\$33.00 (50 tests)	I or II	<ul style="list-style-type: none"> - Alliance for the Chesapeake Bay and affiliate organizations - Lake Anna Civic Association - Upper Rappahannock Watershed Stream Monitoring Program
Various narrow range field test kits (LaMotte #2105, 2107, 2109, 2110, 2111, 2112) Use appropriate range	\$33.00 (50 tests)	I or II	<ul style="list-style-type: none"> - Alliance for the Chesapeake Bay and affiliate organizations - Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University)
Hach Color Disk Field Test Kits (#1470-04, 1470-14, 1470-06, 1470-08, 1470-09)	\$55.00 (200 tests)	I	None known
Colorimeter	\$150-\$1000	I	<ul style="list-style-type: none"> - Friends of Powhatan Creek Watershed
pH Tester (Oakton Testr 2) *Must use standard buffers for calibration *Testr 2 meets DEQ's QA/QC requirements while Testr 1 does <u>not</u> .	\$75.00	I, II, or III	<ul style="list-style-type: none"> - Alliance for the Chesapeake Bay and affiliate organizations
Meters (a multi-parameter meter is more cost-effective than a single parameter meter) *Must use standard buffers for calibration	\$200-\$1000 (pH only) \$900-\$5,000 (multi-parameter)	I, II, or III	<ul style="list-style-type: none"> - Friends of the Shenandoah River and affiliate organizations - Loudoun Wildlife Conservancy

Chapter 6

Nutrients

What Are Nutrients?

Nutrients are necessary for the survival and growth of aquatic plants which are the base of the food chain for all other aquatic organisms. Although a number of nutrients (such as nitrogen, phosphorus, silica, carbon, potassium, calcium, and magnesium) are needed by plants for growth and reproduction, nitrogen and phosphorus are the two of particular interest that are more commonly monitored by volunteer monitoring programs. Nitrogen and phosphorus are the nutrients that limit plant growth in most aquatic systems. In this manual, we are referring to nitrogen and phosphorus when we speak about *nutrients*. The different forms of nitrogen and phosphorus will be discussed in further detail later in this chapter in the section entitled *Sampling and Quality Assurance/Quality Control (QA/QC) Considerations*.

Why Monitor Nutrients?

Nutrient levels in an aquatic system vary depending upon temperature, rainfall, runoff, biological activity, and the flushing of the aquatic system. Nutrient levels are generally higher in the spring and early summer and impact the aquatic system in several ways. High nutrient levels can accelerate eutrophication of a waterway. Eutrophication is characterized by abundant growths of phytoplankton (microscopic plants and algae) called algal blooms that may block sunlight from submerged aquatic vegetation (see Chapter 10). These algal blooms result in lower dissolved oxygen levels as decomposition of their organic matter consumes the dissolved oxygen.

Nutrient concentrations in aquatic systems are influenced by both natural and human sources. Natural sources of nitrogen and phosphorus include decomposition of organic matter, nitrogen fixation of atmospheric nitrogen by certain bacteria and algae, and geologic formations rich in nitrogen or phosphorus. Human sources include discharges from wastewater treatment plants, stormwater runoff, livestock wastes, fertilizer runoff from lawns and agricultural fields, groundwater seepage from failing septic systems, planting of nitrogen fixing plants (such as clover or beans) in agricultural fields, and atmospheric deposition (including acid rain) from the burning of fossil fuels.

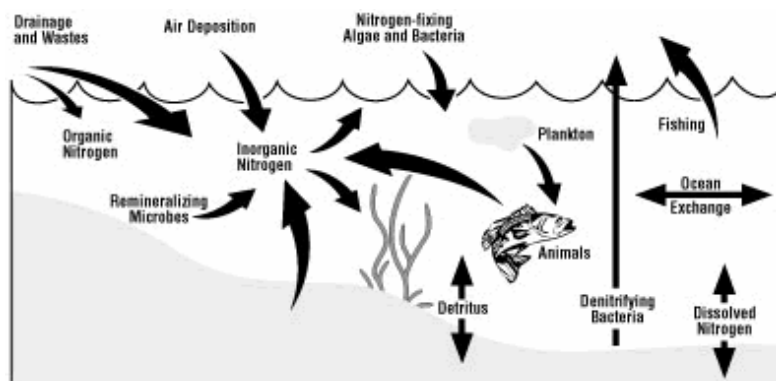


Figure 6-1. The nitrogen cycle (from *Volunteer Estuary Monitoring: A Methods Manual, Second Edition*).

What Do Your Nutrient Results Mean?

Developing nutrient criteria for the nation's waters is currently a hot issue. The debate centers on determining the limiting nutrient for a particular type of water in a particular ecoregion. Currently, Virginia has not yet adopted water quality standards for nutrients except for total ammonia as it relates to the toxicity to aquatic animals and nitrate for public drinking water supplies. Nitrate levels in public water supplies should not exceed 10,000 ug/l (micrograms/liter), or 10 mg/l.

The Virginia Department of Environmental Quality (DEQ) currently designates "nutrient enriched waters" where there is degradation due to excessive nutrients. For free-flowing streams, the maximum concentration for total phosphorus is 200 ug/l, or 0.20 mg/l; while it is only 50 ug/l, or 0.05 mg/l, for lakes. DEQ has recently begun the process of developing nutrient water quality standards. Nutrient water quality standards are scheduled to be adopted as follows: in 2005 for tidal tributaries to the Chesapeake Bay; in 2006 for lakes; and in 2007 for freshwater streams.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for nutrients are discussed below.

Different Forms of Nutrients

Nitrogen and phosphorus can be found in aquatic systems in many different forms, or species. While monitoring each individual species may help determine the source, it is important to remember that, when developed, Virginia's water quality standards may be for total nitrogen and total phosphorus.

Nitrogen Species

In aquatic systems, nitrogen exists in various inorganic chemical species (ammonia, nitrate and nitrite are all common components of synthetic fertilizers) and in particulate and dissolved organic and inorganic forms. Total nitrogen is a combination of nitrate, nitrite and total Kjeldahl nitrogen (TKN). TKN is organic nitrogen, which is a complex mixture of compounds primarily derived from living and dead organisms.

Nitrification is the process whereby some bacteria convert ammonium to nitrite and then nitrite to nitrate. Since this process consumes oxygen, a system with low dissolved oxygen levels may experience increased concentrations of ammonia or

nitrites. Nitrate is highly water-soluble and is easily carried by runoff. At high levels, nitrates and ammonia can be toxic. The natural level of ammonia and nitrate in discharge from wastewater treatment plants can be as high as 30 mg/l.

Phosphorus Species

In aquatic systems, phosphorus exists as orthophosphate (dissolved and inorganic), total phosphorus (dissolved and particulate), organic phosphate, and polyphosphate (from detergents). Orthophosphate is commonly measured and is found in fertilizers. Phosphate that is not associated with organic material is inorganic and this inorganic phosphorus is the form required by plants. Animals can use either organic or inorganic phosphate. Many phosphorus species attach to soil particles and are transported with sediment runoff. Phosphate in the aquatic system may bind to minerals in the sediment resulting in low phosphorus levels in the water. During conditions of no dissolved oxygen, bound phosphorus can be released into the water column triggering algal blooms.

Monitoring phosphorus is challenging because it involves measuring very low concentrations (0.01 mg/l or even lower). Even such very low concentrations of phosphorus can have a dramatic impact on streams. Methods that do not have detection limits this low can be used to identify potential problem areas.

When to Sample

Since nutrient concentrations are highly variable, it is best to sample for nutrients throughout the year and over a long period of time to obtain a more complete picture of water quality. Frequent sampling can also facilitate explaining variability in the data.

Choosing a Method

Choosing a method for nutrient analysis can pose a dilemma. Your decisions on the goals of your program and the intended data use will determine the method that you should use. At this time, laboratory analyses of nutrients are the only methods that yield results accurate enough for DEQ's water quality assessments. Other methods may be used for educational or screening purposes.

Test Kits

Different forms of nutrients can be measured using test kits to screen for potential problem areas or "hot spots". In general, nutrients are found in low concentrations that may be lower than the detection limits of the test kits. However, test kits that detect low levels can collect information about periodic increases in nutrient concentrations and help target areas where more advanced monitoring may be of interest. Data collected from nutrient test kits are not acceptable for use by DEQ for water quality assessments.

Colorimeters

This instrument measures nutrient concentrations based upon the absorption spectrum of the parameter. This instrument requires proper maintenance and calibration. Although this instrument has a lower detection limit than test kits, the data collected with this instrument are not acceptable for use by DEQ since the detection limit is not generally low enough to accurately measure nutrient concentrations.

Laboratory Analysis

Laboratory analysis of nutrients is the most accurate method for obtaining nutrient data. Even laboratory analysis requires strict quality assurance and quality control methods. Recommended QA/QC measures include:

- Proper Preservation: Table 6-1 describes acceptable preservation methods of water samples for lab analysis of various nutrient species.
- Field duplicates: A field duplicate is simply a second water sample taken at the same time as another sample to measure the reproducibility of the monitor, method and/or analyst. It is recommended that field duplicates are collected randomly for 10% of your samples (for a large sample size, 5% is acceptable). For example, if you collect 50 samples, you should collect field duplicates at 5 of those sites and label the duplicate samples.
- Field equipment blanks are only necessary if water samples are collected in a bucket or other sampling device and transferred into the sample container. A field equipment blank is simply a contaminant-free sample (distilled or deionized water) used to detect contamination of the collection device or cross-contamination between sites. A field equipment blank is collected and transferred in the same manner as the stream water sample. It is recommended that you collect field equipment blanks randomly for 10% of your samples (for a large sample size, 5% is acceptable).

Table 6-1. Preservation Methods for Laboratory Analysis of Various Nutrients

Parameter	Chill on Ice to <4°C (immediately)	Lower pH to < 2 (add 2 ml of sulfuric acid to 1 liter of sample)	Freeze (in the lab)	Holding Time
Total nitrogen	YES		YES	28 days
Ammonia/TKN	YES	YES		28 days
Nitrate/Nitrite	YES			48 hours
Total phosphorus	YES	YES	YES	28 days
Orthophosphorus	YES			48 hours

Summary of Nutrient Monitoring Methods

Method (Vendor and Catalogue #)	Approximate Cost	Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)	Organizations Using Method
Nitrate Test Kits (LaMotte #3119, 3519, 3615, 3354; Hach #14161-00)	\$53-\$83	I	<ul style="list-style-type: none"> - Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University) - Assateague Coastal Trust - Northern VA Soil & Water Conservation District
Ammonia Test Kits (LaMotte #3304 ; Hach #2241-00, 24287-00)	\$55	I	<ul style="list-style-type: none"> - Alliance for the Chesapeake Bay - Assateague Coastal Trust
Nitrite Test Kits [LaMotte #7674 (50 tests) ; Hach #21820-00 (100 tests)]	\$53-\$79	I	<ul style="list-style-type: none"> - Northern VA Soil and Water Conservation District
Phosphate Test Kits [LaMotte #3121, 7416, 3119 (50 tests) ; Hach #2248-00, 2248-01 (100 tests)]	\$65-\$87	I	<ul style="list-style-type: none"> - Assateague Coastal Trust - Loudoun Soil and Water Conservation District
Colorimeter	\$150-\$1000	I	<ul style="list-style-type: none"> - Friends of Powhatan Creek Watershed
Lab	\$7.50- \$15.00 per sample per species*	I, II or III	<ul style="list-style-type: none"> - Friends of the Shenandoah River and affiliate organizations - Ferrum College (Smith Mountain Lake & Claytor Lake Programs) - Upper Rappahannock Watershed Stream Monitoring Project

*These costs are based upon submitting samples to the state laboratory, the Division of Consolidated Laboratory Services. This lab is only available to government organizations and nongovernmental organizations that receive state funding.

Section 3: Biological Monitoring

Chapter 7: Benthic Macroinvertebrates

Chapter 8: Bacteria

Chapter 9: Chlorophyll *a*

Chapter 10: Submerged Aquatic Vegetation (SAV)



Photos Courtesy of the Virginia Department of Conservation and Recreation and Alliance for the Chesapeake Bay

Chapter 7

Benthic Macroinvertebrates

What Are Benthic Macroinvertebrates?

Benthic macroinvertebrates are organisms that live on the bottom of a body of water (benthic), lack a backbone (invertebrate) and are visible to the eye (macro). Benthic macroinvertebrates include insects in their larval or nymph stages, crustaceans (such as Crayfish), and mollusks (such as clams).



Damselfly larva.

Why Monitor Benthic Macroinvertebrates?

Volunteer monitoring programs in wadable, nontidal freshwater streams commonly monitor benthic macroinvertebrates. They are good indicators of water quality because:

- They are affected by the physical, chemical, and biological conditions of the stream.
- They show the effects of short and long-term pollution events.
- They may show the cumulative impacts of pollution.
- They may show impacts from habitat loss not detected by traditional water quality assessments.
- They are important in the food web of the stream.
- Some are very intolerant of pollution; while others are tolerant of pollution.
- They are relatively easy to monitor.

Benthic macroinvertebrate monitoring is often a popular choice for volunteer monitoring programs in nontidal freshwater streams because it is generally less expensive than other kinds of monitoring and the monitoring events can be less frequent while showing cumulative effects. Many volunteers, especially children, enjoy collecting “bugs.”

What Do Your Macroinvertebrate Results Mean?

The study of benthic macroinvertebrates generally includes collecting samples from the habitat(s) of the organisms and identifying and sorting the organisms in the collection. After all organisms have been identified (to order or family depending upon methodology), a water quality index may be calculated depending upon the methodology you choose to use. The calculation of the water quality index varies from one methodology to another but the end result may be a number that corresponds to a water quality rating.

Information about the sources of pollution cannot be obtained from a single macroinvertebrate survey alone. Sources of pollution can be inferred from a macroinvertebrate study by incorporating a habitat and watershed assessment and looking at conditions upstream and downstream of potential sources of pollution. While chemical monitoring can only describe water quality at the moment the water is monitored, the macroinvertebrate community shows cumulative impacts.

Sampling Considerations

There are two programs in Virginia that provide training and certification of volunteers for macroinvertebrate monitoring: the Virginia Save Our Streams Program (VA SOS) and the Audubon Naturalist Society (ANS). These methods are appropriate for nontidal, wadeable freshwater streams with riffles (areas where the water bubbles over the rocks) generally located west of the fall line (parallels I-95) in Virginia.



Stream with riffles (*photo courtesy of VA Save Our Streams*).

In 2001, VA SOS began using a modified method based upon a two-year scientific study of the traditional Save Our Streams method. This two-year study resulted in changes to the collection and identification procedures to yield results that more closely matched those obtained when using professional methods (please see <http://www.vasos.org/ValidationStudy.htm> for a copy of the study by Engel and Voshell, 2002). Although VA SOS trains and certifies volunteers across Virginia in the modified method (where appropriate geographically), the traditional method may still be used for educational purposes only. Monitoring results obtained by certified VA SOS monitors using the modified VA SOS method are used by the Virginia Department of Environmental Quality (DEQ) for water quality assessments.

The ANS uses a modified version of the U. S. Environmental Protection Agency (EPA) Rapid Bioassessment II Protocol (this professional method is described later in this chapter) for macroinvertebrate collection and habitat assessment. ANS provides training and certification for volunteers in Northern Virginia, including macroinvertebrate identification to order and family levels, protocol implementation, and habitat assessment. Training is offered at their sanctuaries in Fairfax and Loudoun Counties. Monitors work in teams led by a certified leader. Monitoring results obtained using the ANS method are used by DEQ for water quality assessments.



Volunteers collecting macroinvertebrates in eastern Virginia (*photo courtesy of Alliance for the Chesapeake Bay*).

Additionally, VA SOS in conjunction with Randolph-Macon College is developing a protocol for macroinvertebrate monitoring in nontidal, freshwater streams that lack riffles as found in central and eastern Virginia. Once this method is developed this manual will be updated (contact VA SOS at <http://www.vasos.org> for further information). Although benthic macroinvertebrates are found in tidal and estuarine (salt) waters of Virginia, there is currently no method appropriate for volunteers to use for monitoring these organisms.

In addition to the volunteer methods for macroinvertebrate monitoring, professional programs typically use methods known as Rapid Bioassessment Protocols (RBP) developed by the U. S. Environmental Protection Agency. RBP methods require identification of organisms to either the family level (RBP II) or the genus/species level (RBP III) and therefore, require extensive training as well as a lab for identification.

Please see *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers; Periphyton, Benthic Macroinvertebrates and Fish*, second edition, EPA Publication 841-B-99-002, (<http://www.epa.gov/owow/monitoring/rbp/>) for more information.

Summary of Benthic Macroinvertebrate Monitoring Methods

Method	Approximate Cost	Monitoring Level (see Appendix 9)	Organizations Using Method
Modified Virginia Save Our Streams Method	One time purchase of basic monitoring equipment about \$60 (includes net, waders, and other supplies) http://www.vasos.org/7equipchec.htm	I or II	Virginia Save Our Streams Program provides training and certification to interested organizations http://www.vasos.org
Traditional Virginia Save Our Streams Method	One time purchase of basic monitoring equipment about \$60 (includes net, waders, and other supplies) http://www.vasos.org/equipchec.htm	I or II	Virginia Save Our Streams Program provides training to interested educational programs to interested organizations http://www.vasos.org
Audubon Naturalist Society	One time purchase of basic monitoring equipment about \$241(includes net, field scope, and other supplies)	I or II	Audubon Naturalist Society provides training to interested individuals in Northern Virginia http://www.audubonnaturalist.org/rustsanct.htm

Chapter 8

Bacteria

What Are Bacteria?

Bacteria are single-celled organisms that occur in a variety of forms and have a wide range of properties. Some cause disease while others decompose decaying organic material and serve as food for other organisms in the food chain.

Why Monitor Bacteria?

Pathogenic (disease-causing) bacteria, viruses, and protozoans found in fecal waste can cause a variety of illnesses and diseases when ingested during recreational contact or consumed in contaminated water and shellfish. Fecal waste from humans or other warm-blooded animals may enter a waterbody from various sources including faulty wastewater treatment plants, livestock, malfunctioning septic systems, untreated sewage discharge, pets, stormwater runoff, wildlife, or boat waste. Since it is not practical to monitor every pathogen, “indicator” species are monitored. The presence of indicator species suggests the presence of fecal waste that may include pathogenic microorganisms that pose a health risk. In addition to the possible health risk associated with elevated levels of fecal material, it can also cause cloudy water, nutrient enrichment, unpleasant odors, and an increased oxygen demand (please see Chapters 4 and 6).

Which Bacterial Indicator Should You Use?

Bacterial indicators commonly measured by professional and volunteer monitoring programs include fecal coliform, *Escherichia coli* (*E. coli*) and enterococci. These indicators are normally prevalent in the fecal waste of warm-blooded animals and humans. This manual does not discuss monitoring total coliforms (*E. coli* and fecal coliforms belong to this larger group) since the presence of total coliforms does not necessarily indicate fecal contamination. However, total coliforms may be useful for testing drinking water because their presence indicates contamination of a drinking water supply by an outside source.

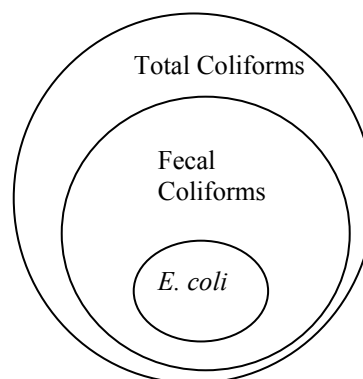


Figure 8-1. Relationship of bacterial indicators.

Fecal Coliform

Fecal coliforms, a subset of total coliform bacteria, are fecal-specific in origin. Even this group contains a genus, *Klebsiella*, with species that are not necessarily fecal in origin (often associated with textile or paper mill wastes). Fecal coliforms have historically been monitored by the Department of Environmental Quality (DEQ) as the indicator bacteria for surface waters. With the implementation of the new state water quality standard for bacteria, DEQ has begun to monitor more fecal-specific bacteria (*E. coli* and enterococci).

Escherichia coli (E. coli)

E. coli is a species within the fecal coliform group that is specifically associated with the fecal waste of warm-blooded animals. In freshwater, *E. coli* corresponds more closely with swimming-related illnesses than fecal coliforms. DEQ has begun monitoring *E. coli* at freshwater stations.

Enterococci

Enterococci are another group of bacteria found mainly in the intestinal tract of warm-blooded animals. It is not a type of coliform bacteria but a subgroup of the fecal streptococci group. Since EPA recommends enterococci for testing marine recreational waters because of correlation with swimming-related illnesses, DEQ has begun monitoring for enterococci at saltwater stations.

What Do Your Bacteria Results Mean?

A new water quality standard for bacteria was adopted by Virginia and became effective in January 2003 (Table 8-1). The new standard changes the indicator from fecal coliform to *E. coli* in freshwater and to enterococci in salt and transitional zone waters. During this transition to the new standard, a water quality standard for fecal coliform (revised from the old fecal coliform standard) will also apply until 12 or more data points for the new indicators are collected or until June 2008. After June 2008, only water quality standards for *E. coli* and enterococci will apply.

Table 8-1. Virginia Water Quality Standards for Bacteria (effective January 2003).

Indicator	Single Sample	Revised Single Sample Standard	Geometric Mean* (of 2 or more samples collected within same calendar month)
Fecal Coliform		10% of the number of samples taken during a calendar month should not exceed 400 colonies/100 ml water	200 colonies/100 ml water
<i>E. coli</i> (freshwater)	235 colonies/100 ml water		126 colonies/100 ml water
Enterococci (salt/transitional zone waters)	104 colonies/100 ml of water		35 colonies/100 ml of water

*The geometric mean can be calculated using the built-in formula in an Excel spreadsheet or by taking the nth root (where n= the number of data points) of the product of the individual data points.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for bacteria are discussed below.

Choosing a Method

Simplified Testing Methods

Presence-Absence Tests

These simple tests are designed to determine whether the target bacteria are present in a water sample. They are appropriate for educational purposes and for determining the presence of bacteria in drinking water. A variety of companies sell these test kits. Presence-absence tests are not used by any water quality monitoring programs in Virginia because they do not provide useful information for surface waters since bacteria are present in all surface waters.

Coliscan Easygel

Coliscan Easygel (Micrology Labs, Appendix 8) is simple to perform and relatively inexpensive. The Coliscan Easygel method measures total coliforms and *E. coli*. A water sample is added to a liquid medium and poured onto a treated Petri dish. Incubation is highly recommended. Inexpensive home-made incubators can be easily constructed.

The Coliscan Easygel method was compared to laboratory analysis and found to be an acceptable tool for screening purposes although the data cannot be used directly by DEQ for water quality assessments. This method is important because it can assist you in locating “hot spots” for fecal contamination and target areas for more extensive monitoring.

Colilert and Colilert-18

Colilert and Colilert-18 (Idexx Laboratories, Appendix 8) are based upon the most probable number method (see lab analysis section below) to detect the presence or absence of total coliforms and *E. coli*. The Colilert-18 method is for use in saltwater while Colilert is designed for freshwater. The U. S. Environmental Protection Agency (EPA) has approved this method for drinking water; but has not yet approved it for surface waters. At the time of publication of this manual, the Colilert method is under evaluation by DEQ. Bacterial data collected using this method will not be used by DEQ for water quality assessments until the method is

approved by EPA for surface water or comparison data demonstrates that the Colilert method produces data relatively comparable to an approved method.

Laboratory Analysis

At the time of the publication of this manual, bacterial monitoring data must be collected under a DEQ-approved quality assurance project plan (QAPP) where the samples are analyzed by a laboratory using a DEQ-approved analysis method to be included in DEQ's water quality assessments. Some water quality monitoring programs in Virginia conduct these laboratory tests themselves, while others send water samples to a commercial laboratory.

Membrane Filtration (MF)

Membrane filtration (MF) is the laboratory method used by most volunteer monitoring groups. The MF procedure may not be useful in highly turbid waters since the filter can become clogged. For this method, the sample water is filtered and the filter is placed in a Petri dish along with a media ("food" for selected bacteria) and incubated. MF yields a direct count of bacteria colonies per 100 ml of water. This analysis method is often used to analyze water samples collected in freshwater areas. For more information on this procedure, please see Standard Method #9222D (APHA, 1998) for fecal coliforms and the EPA Method #1103.1 for *E. coli*.



Membrane filtration of water sample for bacterial analysis (photo by Katie Register).

Most Probable Number (MPN)

The most probable number (MPN) method is more commonly used in saltwater areas and is the only method approved for use in classifying shellfish-growing waters. This method is more expensive because it is labor intensive. A single water sample is added to a series of test tubes along with a media and incubated. Each test tube is determined to be positive or negative and the number of positive results corresponds to the probability that the water sample contained a specific (the most probable number) number of bacteria. For more information on this procedure, please see Standard Method #9221E for fecal coliforms and #9221F for *E. coli* (APHA, 1998).

Quality Assurance/Quality Control Issues

Sample Collection

It is preferred that you collect water samples for bacterial analysis directly from the stream, either by wading or using a pole with a holder for the sample bottle. If this is not possible for safety reasons, the water sample may be collected in a bucket or other

sterile container and transferred to the sterile sample container. Do not rinse sample bottles or collection device with sample water.

Some sample containers obtained from a lab contain a sodium thiosulfate tablet. This tablet is not necessary for surface water samples unless chlorine may be present. The purpose of the tablet is to neutralize chlorine in drinking water samples.

Field Equipment Blanks

Field equipment blanks are only necessary if water samples are collected in a bucket or other sampling device and transferred into the sample container. A field equipment blank is simply a contaminant-free sample (distilled or deionized water) used to detect contamination of the collection device or cross-contamination between sites. A field equipment blank is collected and transferred in the same manner as the stream water sample. It is recommended that field equipment blanks are collected randomly for 10% of your samples (for a large sample size, 5% is acceptable). For example, if you collect 50 samples, you should collect field equipment blanks at 5 of those sites and label the blank samples.

Field Duplicate Samples

Due to the nature of bacterial samples, a high degree of variation is normally expected in field duplicate samples. Therefore, DEQ does not recommend the collection of these samples.

Holding Time

A holding time of 26 hours is acceptable for ambient water quality samples (i.e. non-drinking water and non-enforcement samples). Samples must be chilled to less than 4°C immediately after collection and stored in the dark.

Summary of Bacteria Monitoring Methods

Method	Approximate Cost	Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)	Organizations Using Method
Various Presence-Absence Tests	\$11	I	None known
Coliscan Easygel (measures <i>E.coli</i>)	\$1.85 per sample	I	- Alliance for the Chesapeake Bay and affiliate organizations
Idexx Colilert (measures <i>E.coli</i>)	\$20-\$25 per sample	I	- Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University)
Lab - Membrane Filtration	\$20.00 per sample (<i>E. coli</i>)*	I, II, or III	<ul style="list-style-type: none"> - Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University) - Ferrum College (Smith Mountain Lake & Claytor Lake Programs) - Upper Tennessee River Roundtable affiliate organizations
Lab - Most Probable Number	\$20.00-70.00 per sample*	I, II, or III	- Virginia Department of Health Division of Shellfish Sanitation

*These costs are based upon submitting samples to the state laboratory, the Division of Consolidated Laboratory Services. This lab is only available to government organizations and nongovernmental organizations that receive state funding.

Chapter 9

Chlorophyll *a*

What is Chlorophyll *a*?

Chlorophyll is the pigment that allows plants (including algae) to undergo photosynthesis. Chlorophyll *a* is the predominant type of chlorophyll found in algae and phytoplankton (microscopic plants).

Why Monitor Chlorophyll *a*?

Chlorophyll *a* is measured to estimate the abundance of algae and phytoplankton in the water. Since chlorophyll *a* concentrations can vary among algal species and with differing light conditions, chlorophyll *a* is not considered a precise measurement of the abundance of algae. Large amounts of chlorophyll *a* indicate algal blooms that are caused by excessive nutrients as discussed in Chapter 6.

In lakes, chlorophyll *a* can be used to evaluate the trophic (aging) status of the lake. As lakes “age”, the amount of plant and algal life that the lake can support increases as nutrients are added. Nutrients introduced from human activities can lead to an excessive amount of plant and algal life, which decreases water clarity and leads to interference with recreational activities and decreased dissolved oxygen levels as the plants decay.

What Do Your Chlorophyll *a* Results Mean?

The Department of Environmental Quality (DEQ) has begun to monitor for chlorophyll *a* suspended in the water column at some of its chemical (ambient) water quality monitoring stations, particularly in estuarine areas. DEQ currently designates “nutrient enriched waters” where there is degradation due to excessive nutrients. For tidal fresh waters, estuaries and lakes, the screening value for chlorophyll *a* is 50 ug/l (micrograms/liter), or 0.50 mg/l.

The higher the concentration of chlorophyll *a* present the more algae and phytoplankton present. Although large amounts of chlorophyll *a* indicate algal blooms, too little chlorophyll *a* would mean that not enough food is available for fish and aquatic animals.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Only a few citizen monitoring programs in Virginia measure this parameter since the water samples collected must be analyzed in a laboratory. Once collected, the water samples must be filtered under pressure within two hours of collection.

Sample Collection

Water samples for chlorophyll *a* analysis can be collected as grab samples (where a sample bottle is used to collect water at a particular depth) or as integrated samples (where a series of grab samples are taken at different depths and mixed together). An integrated sample may be collected by various methods: lowering a weighted sampler that collects water as it is lowered through the water column, using a pump to collect a water sample, or using a weighted hose that is crimped to capture the water.

Collecting a grab sample may be easier and less expensive; but in some situations, a single grab sample near the surface may not be representative of the algal biomass present. In shallower waters that are well-mixed, algae may be distributed evenly and a grab sample may be representative. However, in some waters algae may be distributed unevenly in the water column and an integrated sample would be preferable.

Depth

If you decide to collect an integrated sample, you will need to decide how deep to collect the water sample. Some programs, such as the Smith Mountain Lake Water Quality Monitoring Program coordinated by Ferrum College, collect the integrated sample through the photic zone. This is the depth in the water column where enough light penetrates to allow photosynthesis to occur and is usually estimated based on Secchi disk depth (usually one to 3.5 times the Secchi depth). Please see Chapter 12 for a description of how to measure water clarity using a Secchi disk. Sampling the upper warm water (epilimnion) and transitional water layers (thermocline) may also be appropriate. The thermocline is just below the epilimnion which prevents mixing of the warm epilimnion and the cooler bottom water of a lake.

Quality Assurance/Quality Control Issues

Chlorophyll *a* must be analyzed in a laboratory. Recommended QA/QC measures include:

- Proper Preservation: Samples should be filtered within two hours of collection. The filter can be frozen and kept in the dark for up to 28 days.
- Field duplicates: A field duplicate is simply a second water sample taken at the same time as another sample to measure the reproducibility of the monitor, method and/or analyst. It is recommended that you collect field duplicates randomly for 10% of your samples (for a large sample size, 5% is acceptable). For example, if you collect 50 samples, you should collect field duplicates at 5 of those sites and label the duplicate samples.
- Field equipment blanks are only necessary if water samples are collected in a bucket or other sampling device and transferred into the sample container. A field equipment blank is simply a contaminant-free sample (distilled or deionized water) used to detect contamination of the collection device or cross-contamination between sites. A field equipment blank is collected and transferred in the same manner as the stream water sample. It is

recommended that field equipment blanks are collected randomly for 10% of your samples (for a large sample size, 5% is acceptable).

Summary of Chlorophyll *a* Monitoring Methods

Method	Approximate Cost	Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)	Organizations Using this Method
Laboratory	\$12.00*	I or II	<ul style="list-style-type: none">- Alliance for the Chesapeake Bay and affiliate organizations- Ferrum College (Smith Mountain Lake & Claytor Lake Programs)

*This cost is based upon submitting samples to the state laboratory, the Division of Consolidated Laboratory Services. This lab is only available to government organizations and nongovernmental organizations that receive state funding.

Chapter 10

Submerged Aquatic Vegetation (SAV)

What Are Submerged Aquatic Vegetation (SAV)?

Submerged aquatic vegetation are rooted vascular plants found in the waters of estuaries where the water is shallow and clear enough for sunlight to penetrate the water column so that photosynthesis can occur. SAV is completely submerged and does not include algae or floating plants. Salinity, temperature and substrate determine where each species of SAV can grow. Over the years, SAV beds have declined in the estuarine waters of the Chesapeake Bay and its tributaries. Nutrients, sediments from runoff, and herbicides cause a decline in SAV population.

Why Are SAV Important?

SAV beds provide food and habitat for waterfowl, fish, shellfish, and invertebrates. Juvenile blue crabs and fish use the SAV beds for cover, while the leaves of the plants serve as attachment sites for eggs and small organisms. SAV use up excess nutrients that might contribute to eutrophication of an estuary by storing a summer pulse of nutrients for later release in the fall as the plant material decomposes. SAV beds trap sediment and reduce shoreline erosion by reducing the energy of incoming waves. Photosynthesis of SAV adds oxygen to the water.

Monitoring the Habitat Requirements for SAV

The Alliance for the Chesapeake Bay (ACB) coordinates the monitoring of the water quality requirements for SAV with several other volunteer monitoring organizations. Since available sunlight is the most important factor affecting SAV growth, the amount of light available is measured by various means. ACB uses five measures to define the amount of light available to SAV. Light penetration is measured with a Secchi disk or turbidity tube. Total suspended solids (TSS) and chlorophyll *a* (estimates the amount of algae and plankton) are measured because they block sunlight from SAV. Dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) are measured because they can lead to algal blooms that can also block sunlight from SAV. All of these parameters, except for light penetration (as measured by the Secchi disk), must be measured in a laboratory from samples collected in the field. Salinity is also recommended as a monitoring parameter in order to determine the basic salinity regime of the site. Please see the chapters in this manual specific to these parameters for more information.



Volunteers filtering water sample for analysis of the water quality requirements for SAV (photo courtesy of Alliance for the Chesapeake Bay).

What Do Your SAV Habitat Requirement Results Mean?

This section was adapted from the Chesapeake Bay Program document entitled *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis* (August 2000).

The Chesapeake Bay Program is the regional partnership that directs and conducts the restoration of the Chesapeake Bay. Monitoring, both pre and post planting, is a crucial component of any SAV planting project. Monitoring is important to identify and prioritize potential restoration sites with sufficient water quality. Likewise, monitoring is important to avoid restoration at a site with poor water quality. Post planting monitoring, including plant survival monitoring, is important in order to provide information about why a restoration project was unsuccessful or successful.

Water quality monitoring results are compared to habitat requirements developed by Chesapeake Bay Program scientists that are believed to be indicative of good water quality conditions conducive to SAV growth and survival (Table 10-1). SAV habitat parameters include primary and secondary requirements. The primary light requirement is the *minimum light requirement*, also known as the *percent light at the leaf* (PLL). This refers to the percent of light measured just below the surface of the water that reaches the surface of an SAV leaf growing at the sediment surface, after passing through the water column and any material that is accumulated on the SAV leaf surface. PLL can be calculated using water quality data of the five parameters collected by ACB volunteers: Secchi depth, dissolved inorganic nitrogen, dissolved inorganic phosphorous, total suspended solids, and chlorophyll *a*. Secondary requirements included these five parameters as well as the *water column light requirement*, also referred to as the *percent light through the water column* (PLW). This refers to the percent of light measured just below the surface of the water that reaches the sediment surface after passing through the overlying water column, but not through the accumulated material on the SAV leaf surface. PLW should only be used to evaluate water quality conditions only if the parameters necessary to calculate PLL are not available. Other secondary habitat requirements include the four laboratory parameters needed in order to calculate PLL (TSS, DIP, DIN, and Chlorophyll *a*). These four parameters are useful as diagnostic tools used to determine possible explanations of non-attainment of the necessary PLL value.

Table 10-1. Habitat requirements for SAV

Habitat Requirement	How Measured	Minimum Level
Primary		
Minimum Light Requirement, also referred to as the Percent Light at the Leaf (PLL)	Calculated using Secchi depth, DIN, DIP, TSS, and Chlorophyll <i>a</i>	>9 % (tidal freshwater and low salinity regime) ->15% for medium to high salinity regimes
Secondary		
Water Column Light Requirement, also referred to as the PLW (Percent Light through the Water Column)	Calculated using Secchi Depth or light meter	>13 % (tidal freshwater and low salinity regime) ->22% for medium to high salinity regimes
Dissolved inorganic Nitrogen (DIN)	Filtered water sample	<0.01-0.02 mg/l, depending on salinity regime
Dissolved inorganic Phosphorous (DIP)	Filtered water sample	<0.15 mg/l
Total Suspended Solids (TSS)	Water drawn through a filter	<15 mg/l
Chlorophyll <i>a</i> (Chl <i>a</i>)	Water drawn through a filter	<15 µg/l (micrograms per liter)
Epiphyte biomass	Lab measurement of epiphyte growth on Mylar strips	—

Summary of SAV Habitat Requirement Monitoring Methods

Method	Approximate Cost	Monitoring Level	Organizations Using Method
SAV Habitat Requirement Monitoring: 1. field measurements: <ul style="list-style-type: none"> - Secchi depth and/or turbidity tube - salinity 2. lab analysis of dissolved parameters for: ammonia, nitrate, nitrite, orthophosphate, total suspended solids, and chlorophyll <i>a</i>	<ul style="list-style-type: none"> - See Chapters 12 and 13 for field measurements - Lab analysis for all parameters listed: approximately \$31 based on 2003 prices 	I or II	<ul style="list-style-type: none"> - Alliance for the Chesapeake Bay and affiliate organizations

Other SAV Activities in Virginia

Since SAV are sensitive to disturbance, volunteer programs working with SAV should receive proper training and guidance from scientists or government agency representatives.

SAV Plantings

The Alliance for the Chesapeake Bay conducts SAV plantings utilizing the assistance of volunteers in an attempt to stimulate the growth of new SAV beds in areas where water quality and other site conditions (wave energy, soil type, etc.) indicate good conditions for plant survival. Planting is accomplished often with the assistance of volunteer SCUBA divers. Fence enclosures are often constructed around the plantings to minimize potential herbivory and disturbance of the plants from wildlife including turtles, fish, invertebrates, and waterfowl. Water quality and plant monitoring are crucial components of any SAV planting project both before and after the planting.



Volunteers planting SAV (photo courtesy of Alliance for the Chesapeake Bay).

The Chesapeake Bay Foundation (CBF) sponsors the “Grasses for the Masses” and “Grasses in Classes” programs where schools or individuals can grow SAV in aquariums and then participate in a planting project to plant the mature grasses in areas where they may be able to survive.

Underwater Grass Mapping (Groundtruthing)

Volunteers throughout the Chesapeake Bay are recruited during the summer annually to help verify the existence of SAV beds shown in aerial photographs, identify the SAV species, and locate any new beds that might exist. This process is called “groundtruthing.” This activity is coordinated by the Chesapeake Bay Foundation.

For More Information About SAV Activities

- Monitoring Habitat Requirements or Planting SAV
ACB: <http://www.AllianceChesBay.org>
- Classroom – Growing and Planting SAV
CBF: <http://www.cbf.org>
- Mapping SAV
CBF: <http://www.cbf.org>

Section 4: Physical Measures

Chapter 11: Temperature

Chapter 12: Turbidity/Transparency and Total Solids

Chapter 13: Salinity

Chapter 14: Conductivity

Chapter 15: Stream Flow

Chapter 16: Visual Stream Assessments (Stream Walks)

Chapter 17: Riparian Forests and Stream Health



Photos Courtesy of Katie Register and the Loudoun Wildlife Conservancy

Chapter 11

Temperature

Why Monitor Water Temperature?

The rates of biological and chemical processes depend on temperature. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Aquatic organisms are dependent on certain temperature ranges for optimal health. Optimal temperatures for fish depend on the species as some survive best in colder water. Benthic macroinvertebrates are also sensitive to temperature and will move in the stream to find their optimal temperature. For fish, there are two kinds of limiting temperatures: the maximum temperature for short exposures and a weekly average temperature that varies according to the time of year and the life cycle stage of the fish species. Reproductive stages (spawning and embryo development) are the most sensitive stages. If temperatures are outside this optimal range for a prolonged period of time, aquatic organisms are stressed and can die. Also, dramatic shifts in water temperature can cause stress to aquatic organisms.

What Do Your Water Temperature Measurements Mean?

Temperature changes can be caused by weather, removal of stream bank vegetation (which provides shade), impoundments (caused by barriers such as dams), cooling water discharge, urban storm water, and groundwater flowing into the stream. The water quality standards for water temperature in Virginia can be found in Table 11-1 below. Water temperature readings above these numbers indicate a violation of our state's water quality standards.

Table 11-1. Virginia Water Quality Standards for Temperature.

Estuarine Waters	Nontidal Waters – Coastal / Piedmont	Mountainous Zones	Stockable Trout Waters	Natural Trout Waters
Rise above natural temperature (arithmetic average over one hour) should not exceed 3°C.	32°C (maximum)	31°C (maximum)	21°C (maximum)	20°C (maximum)

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for temperature are discussed below.

Air Temperature

If air temperature is measured in addition to water temperature, then the air temperature reading should be measured prior to the water temperature. A wet thermometer can alter the air temperature reading. Air temperatures should be measured in the shade.

Choosing a Method

Temperature must be measured in the stream and may be measured with a thermometer or a meter. Temperature is measured in degrees Fahrenheit (F) or degrees Celsius (C). Temperature should be measured at the same place every time.

Thermometer

Alcohol-filled thermometers are preferred over mercury-filled because they are less hazardous if broken. Armored thermometers for field use can withstand more abuse than unprotected glass thermometers. Thermometer increments should be no more than 1°C.

Meters

Meters used for other measurements, such as pH or dissolved oxygen, may also be used to measure temperature.

Quality Assurance/Quality Control Issues

To assure accuracy, thermometers and meters should be compared with a National Institute of Standards and Technology (NIST) certified thermometer before use (just after purchase) and at least annually. You should compare these instruments at varying temperatures: an ice bath and room temperature. If the difference between your equipment and the

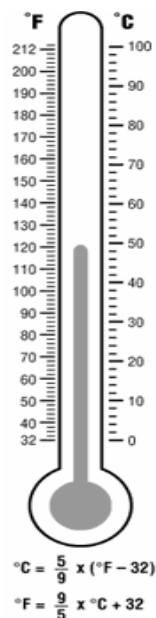


Figure 11-1. Scale for temperature conversion (from *Volunteer Estuary Monitoring: A Methods Manual, Second Edition*).

Where Can You Find a Certified Thermometer?

- DEQ Citizen Monitoring Coordinator
- Local college/university
- Local high school

certified thermometer is greater than 1° C during any of the comparisons, your equipment does not meet the Department of Environmental Quality's (DEQ) QA/QC requirements for data use in water quality assessments. A correction factor for thermometers that do meet this requirement can be developed if you have three comparison temperatures (ice bath, room temperature, and a warm water bath).

Summary of Water Temperature Monitoring Methods

Method	Approximate Cost	Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)	Organizations Using Method
Field Thermometers (non-mercury)	\$18.95	I, II, or III	<ul style="list-style-type: none">- Alliance for the Chesapeake Bay and affiliate organizations- Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University)- Lake Anna Civic Association- Upper Rappahannock Watershed Stream Monitoring Program
Meters	\$900-\$5000 (multi-parameter meters)	I, II, or III	<ul style="list-style-type: none">- Friends of the Shenandoah River and affiliate organizations- Loudoun Wildlife Conservancy

Chapter 12

Turbidity/Transparency and Total Solids

What Are Turbidity/Transparency and Total Solids?

Although the terms “turbidity” and “transparency” are often used interchangeably, they are different measurements. Turbidity is the cloudiness of water determined by measuring how the material suspended in water affects the water’s clarity (how well light passes through the water column). Turbidity does not measure the amount of materials suspended in the water (such as soil, algae, and plankton); but it does measure the amount of light scattered by these particles. Turbid water appears murky or cloudy. Transparency, however, is the clarity (clearness) of the water determined by measuring how well light passes through the water. Both color and suspended materials can affect transparency.

Total solids are materials dissolved or suspended in water. Dissolved solids are less than 2 microns in size while suspended solids are larger than 2 microns. Total solids include soil particles, algae, plankton, dead organic matter, and dissolved inorganic solids such as chloride, nitrate, phosphate, iron, sulfate, magnesium, and calcium.

Why Monitor Turbidity/Transparency and/or Total Solids?

Turbidity/transparency and total solids can be useful indicators of discharges and runoff effects from construction, agricultural practices, logging activity, and waste discharges. Monitoring these parameters may help indicate whether erosion is increasing in a watershed. Turbidity can be caused by any activity that disturbs the stream banks, streambed, or surrounding land that causes sediment runoff into the stream. Turbidity often increases during and just after rainfall, especially in watersheds with a large number of impervious surfaces (rooftops, pavement, parking lots). Stormwater runoff from impervious surfaces rapidly increases the volume and velocity of stream flow, which erodes stream banks.

Sources of Turbidity

- Excessive algal growth due to nutrient enrichment
- Soil erosion from logging, agriculture, or construction
- Stormwater runoff
- Eroding stream banks
- Disturbance of bottom sediments
- Waste discharges

High turbidity levels affect SAV and dissolved oxygen levels. Turbidity reduces the amount of light penetrating the water, reducing photosynthesis and lowering the production of dissolved oxygen. Therefore, high turbidity can reduce SAV. Water temperature also increases with high turbidity levels because suspended particles absorb heat, which reduces dissolved oxygen levels (please refer to Chapter 4). Large amounts of suspended materials can clog fish gills, reduce disease resistance in fish, lower growth rates, and negatively affect egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, smothering fish eggs, benthic macroinvertebrates and the streambed habitat. Toxins also attach easily to suspended solids. The concentration of dissolved solids (such as chloride, nitrate, phosphate, iron, sulfate, magnesium, and calcium) may affect the water balance in the cells of

aquatic organisms making it difficult for them to keep their position in the water column. This will in turn affect the organism's ability to maintain the proper cell density.

What Do Your Turbidity/Transparency and Total Solids Results Mean?

Although there are no water quality standards in Virginia for total solids or turbidity, this information can be useful when looking at trends and can provide information about local land use and sediment control programs. It is important to remember that turbidity/transparency does not measure the amount of suspended solids or the rate of sedimentation. Measurement of total solids is a more direct measure of the amount of material suspended and dissolved in water. Total solids are related closely to stream flow and velocity. Any change in total solids over time should be measured at the same site at the same flow (refer to Chapter 15 for more information on stream flow). Since algae can be the major source of suspended solids in estuarine waters, seasonal variations must also be taken into consideration when monitoring turbidity and total solids.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for turbidity/transparency and total solids are discussed below.

When to Sample

To gain information that would be useful for looking at trends, turbidity or total solids should be monitored relatively frequently year-round for several years. Since turbidity often increases during and immediately after a rainfall, you may consider collecting additional turbidity data to capture the effects of runoff.

Choosing a Method

Secchi Disk

This weighted disk is used to measure transparency (an integrated measure of light scattering and absorption) by lowering the disk into the water and measuring the depth where the disk disappears (Secchi depth). The clearer the water the greater the Secchi depth. Many volunteer programs in lakes or tidal, estuarine waters use the Secchi disk because it is inexpensive and easy to use.



Secchi disk (photo courtesy of Alliance for the Chesapeake Bay).

Secchi disk lines may shrink over time and lines that are marked for measurements should be calibrated regularly. Using a rope that has minimal shrinkage is also recommended. The Secchi disk is not appropriate for use in shallow, fast moving waters.

Transparency Tube

This is a clear, plastic tube with a pattern on the bottom (sometimes a miniature Secchi disk). Water is poured into the tube and the measurement (usually in centimeters) where the pattern disappears is recorded. Waters with extreme colors can interfere with this measurement. The readings from transparency tubes from different manufacturers cannot be compared. This instrument was developed to measure transparency in waters where the Secchi disk is not appropriate (site is too shallow, the flow is too rapid, or there is no dock or pier).

Turbidity Test Kits

Field test kits can be used to measure turbidity. A standardized turbidity reagent is added to a tube of clear water until its cloudiness matches your water sample.

Turbidity Meter (Nephelometer)

A turbidity meter measures turbidity in Nephelometric Turbidity Units (or NTUs). This instrument is not currently used by any citizen monitoring programs in Virginia. A turbidity meter may be used in a laboratory or in the field to measure the turbidity of water samples.

Laboratory Analysis

Lab analysis can be used to determine turbidity and total solids (total dissolved solids or total suspended solids). Total solids must be analyzed in a laboratory by weighing a known volume of sample water and filtering the water sample.

Even laboratory analysis requires strict quality assurance and quality control methods. Recommended QA/QC measures include:

- Proper Preservation: Cool sample to less than 4°C with a holding time of up to seven days.
- Field duplicates: A field duplicate is simply a second water sample taken at the same time as another sample to measure the reproducibility of the monitor, method and/or analyst. It is recommended that field duplicates are collected randomly for 10% of your samples (for a large sample size, 5% is acceptable). For example, if you collect 50 samples, you should collect field duplicates at 5 of those sites and label the duplicate samples.
- Field equipment blanks are only necessary if water samples are collected in a bucket or other sampling device and transferred into the

sample container. A field equipment blank is simply a contaminant-free sample (distilled or deionized water) used to detect contamination of the collection device or cross-contamination between sites. A field equipment blank is collected and transferred in the same manner as the stream water sample. It is recommended that you collect field equipment blanks randomly for 10% of your samples (for a large sample size, 5% is acceptable).

Summary of Turbidity/Transparency and Total Solids Monitoring Methods

Method (Vendor and Model #)	Approximate Cost	Monitoring Level (see Appendix 9)	Organizations Using Method
Secchi Disk	\$30-\$35	I	<ul style="list-style-type: none">- Alliance for the Chesapeake Bay and affiliate organizations- Ferrum College (Smith Mountain Lake & Claytor Lake Programs)- Lake Anna Civic Association
Transparency Tube (Lawrence Enterprises # TT or TTG)	\$34-\$49	I	<ul style="list-style-type: none">- Alliance for the Chesapeake Bay and affiliate organizations- Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University)
Turbidity Test Kit (LaMotte #7519)	\$46	I	<ul style="list-style-type: none">- Northern VA Soil and Water Conservation District
Turbidity Meter (field or lab)	\$800	I	<ul style="list-style-type: none">- Friends of the Shenandoah River and affiliate organizations
Lab analysis of total suspended solids	\$5.00*	I	<ul style="list-style-type: none">- Alliance for the Chesapeake Bay and affiliate organizations- Historic Green Springs

*This cost is based upon submitting samples to the state laboratory, the Division of Consolidated Laboratory Services. This lab is only available to government organizations and nongovernmental organizations that receive state funding.

Chapter 13

Salinity

What is Salinity?

Salinity is the amount of dissolved salts in water. Salinity of tidal rivers and estuaries gradually increases as you move from freshwater tributaries toward the ocean. The freshwater streams and rivers have salinity levels of 0.5 ppt (parts per thousand) or less. Salinity of seawater is relatively constant at more than 30 ppt.

Why Monitor Salinity?

Salinity levels affect the distribution of plants and animals in estuarine environments. Some species can only tolerate certain levels of salinity while others may be able to adjust to any salinity ranging from freshwater to saltwater.

Salinity influences the saturation levels of dissolved oxygen. The amount of dissolved oxygen (DO) the water can hold decreases as the salinity increases. If you are using a meter to measure DO in estuarine waters, you may need to know the salinity level in order to properly calibrate the meter. Salinity can have a role in increasing turbidity by causing dissolved particles in fresh water to clump together upon entering the saltwater. Salinity and water temperature determine the stratification of estuarine waters. Cold, saltwater is denser than warm, freshwater and will sink below the freshwater. Tides and the wind can mix these waters and eliminate the stratification.

What Do Your Salinity Results Mean?

Although there is not a water quality standard in Virginia for salinity, this information can be useful when you are looking at trends, distribution of plant and animals, and other water quality parameters. Salinity is measured in parts per thousand (ppt).

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Weather and Season

During wet weather periods, freshwater enters the estuarine waters lowering salinity levels. Higher salinity levels are found during dry weather periods since less freshwater dilutes the estuarine waters allowing saltwater to intrude into tidal rivers and streams. Seasonal variations and storms also help mix these waters.

Choosing a Method

Density Using a Hydrometer

Hydrometers are inexpensive, fragile and very consistent over time. The hydrometer measures the specific gravity of the water sample, which is the sample's density compared to the density of freshwater. As the salinity of water increases so does its density. Specific gravity is affected by both dissolved and suspended solids; whereas, salinity is based upon dissolved solids only. Therefore, salinity readings measured with a hydrometer are higher when suspended solids are present, especially in low salinity waters.



Figure 13-1. A hydrometer can be used to calculate salinity based upon the density of the water (from *Volunteer Estuary Monitoring: A Methods Manual, Second Edition*).

Refractivity Using a Refractometer

A refractometer is not influenced by suspended solids like the hydrometer. As light travels from air into water, the refractometer measures the change in the light's direction. The extent of this change in direction is influenced in a predictable manner by the salinity of the water. To yield accurate results, the refractometer must be close to the temperature of the sample water.

Meter

Some conductivity meters can calculate salinity from the conductivity reading (conductivity is discussed in Chapter 14). This instrument is not currently used by any citizen monitoring organizations in Virginia. Samples may be transported to a central location for measurements with the meter. See chapter 14 for more information on using a conductivity meter.

Summary of Salinity Monitoring Methods

Method)	Approximate Cost	Monitoring Level (see Appendix 9)	Organizations Using Method
Hydrometer (Greers Ferry 1.000 X 1.070) *Need jar (LaMotte #2-2149)	\$50 for hydrometer and jar	I	- Alliance for the Chesapeake Bay and affiliate organizations - Assateague Coastal Trust
Refractometer	\$90-\$350	I	- Alliance for the Chesapeake Bay and affiliate organizations
Conductivity Meter	Chapter 14	I	None known

Chapter 14

Conductivity

What is Conductivity?

Conductivity (known as specific conductance) is the ability of water to pass an electrical current. Conductivity is affected (raised) by inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge); and sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Oils and many organic compounds do not conduct an electrical current very well and therefore, do not affect conductivity.

The geology of the area through which a stream flows is one of the most important factors affecting conductivity. Streams in areas with granite bedrock usually have lower conductivity levels because granite is composed of relatively inert material that does not conduct an electrical current very well. Alternatively, streams in areas with clay soils usually have a higher conductivity because of the presence of materials that conduct electrical currents. Ground water inflows can have the same effects depending on the bedrock they flow through. Warmer water has a higher conductivity than colder water.

Why Monitor Conductivity?

Conductivity is a useful measure of general water quality. Each stream generally has a relatively constant range of conductivity. Once you establish the baseline conductivity range for a stream, you can compare regular conductivity measurements. Significant changes in conductivity may indicate a discharge or another source of pollution is affecting the stream.

Discharges to streams can affect the conductivity depending on the type of discharge. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate (which would conduct an electrical current well). An oil spill, however, would lower the conductivity. Heavy rains also lower the conductivity since rainwater has a very low conductivity.



Volunteer measuring conductivity with a meter (*photo courtesy of Alliance for the Chesapeake Bay*).

What Do Your Conductivity Results Mean?

Although there are no water quality standards in Virginia for conductivity, this information can be useful when you are looking at trends and general water quality. As discussed in the section above, significant changes in conductivity measurements can indicate potential problems that may need further investigation.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Conductivity is reported at 25°C and is measured in micromhos per centimeter or microsiemens per second. Samples may be transported to a laboratory for the conductivity measurements.

Conductivity meters should be calibrated with standard conductivity buffers (solutions of known specific conductance values) for the range where specific conductance values usually occur. Additionally, the calibration should be confirmed at the end of the sampling day (this is referred to as a “post check”) to determine if the meter has drifted throughout the sampling day. The post check should be conducted similar to the calibration without pressing the calibration button.

Summary of Conductivity Monitoring Methods

Method	Approximate Cost	Monitoring Level (see Appendix 9)	Organizations Using Method
Meter (a multi-parameter meter is more cost-effective than a single parameter meter)	\$60-\$1000 (conductivity only) \$900-\$5,000 (multi-parameter)	I	Ferrum College (Smith Mountain Lake & Claytor Lake Programs)

Chapter 15

Stream Flow

What is Stream Flow?

Stream flow (discharge) is the volume of water that passes a given stream cross section (total width of stream) within a given period of time. Flow is measured by determining the depth and width of a stream and the velocity (speed at which water travels). The area (width multiplied by depth of a stream) multiplied by the velocity gives the discharge. Flow is affected by weather (increases during rain events), seasons (decreases during summer due to evaporation and uptake by vegetation), water withdrawals, water discharges, and the groundwater table level.

Why is Stream Flow Important?

Stream flow impacts water quality and the living organisms and habitats in the stream. The amount of pollution a stream can receive without significantly affecting the water quality partially depends upon the stream flow. Swiftly flowing, large rivers have a greater capacity to dilute pollution than small streams. Stream velocity, which is partly determined by the volume of water in the stream, affects the kinds of organisms that live in the stream (some organisms prefer faster flowing streams while others prefer slower flowing streams). Sediment entering slow flowing streams will settle quickly, while sediment in fast flowing streams will remain suspended longer. Dissolved oxygen is also affected by stream flow since fast moving streams are better aerated, which results in higher dissolved oxygen levels.

What Do Flow Measurements Mean?

Since flow is a function of water volume and velocity, it is usually expressed as cubic feet per second (ft³/sec). Stream flow is needed to calculate how much of a pollutant the stream can receive without violating a water quality standard.

Flow data collected by volunteer monitoring programs is not typically used for TMDLs and permit applications. Data users that generally use flow data for scientific analysis (rather than permitting or other legal matters) have demonstrated an interest in any flow data. Potential uses include: conducting minimum in-stream flow analysis; relating flow measures to Wolman Pebble Counts (and Riffle Stability Index developed by the United States Forest Service); and relating flow measures to benthic macroinvertebrate populations.

Measurement Considerations

When considering measuring flow in your watershed, it is recommended that you first determine if your watershed has a stream gauge collecting flow data operated by the Department of Environmental Quality (DEQ) or the U. S. Geological Survey (USGS). USGS and DEQ work cooperatively to maintain a network of approximately 161 continuous stream flow gauging stations across Virginia. The flow data for most of these stations can be found in real-time

(updated every 1-4 hours) online at <http://www-va.usgs.gov>. The flow of most streams in Virginia is not determined on a consistent basis. In most cases where real flow data does not exist, flow is estimated by interpolating flow data from an existing gauge to the stream in question. DEQ and USGS measure flow using methods derived from USGS (as outlined in Rantz, S.E., and others, 1982, *Measurement and Computation of Streamflow: Volume 2. Computation of Discharge*. U. S. Geological Survey Water-Supply Paper. 2175).

One method for measuring discharge (the method most commonly used by DEQ and USGS staff) is conducted by wading into the stream. The width of the stream is divided into small units (stations) and several measurements are taken at each station: depth, width, and velocity. There are several different ways to measure velocity. One way involves floating an object downstream and measuring the distance it travels in a particular amount of time. Another method for measuring a stream's velocity uses a current meter. At each station, the depth (in feet) is multiplied by width (in feet) by the velocity (in feet per second). The product of these three numbers gives the discharge for that station in cubic feet per second. The discharges for each station are added to obtain the total discharge for the stream at that cross section.

The Virginia Save Our Streams Program (VA SOS) evaluated how flow measures are collected across the country and how flow measures collected by volunteers can be used. From this research, VA SOS found that flow is not commonly measured by citizen monitoring programs due to the difficulty in obtaining data that is useful to water quality professionals. It is important for volunteer monitoring programs to obtain the most accurate estimate of stream flow possible with the equipment and expertise of the organization.

Summary of Stream Flow Monitoring Methods

Method	Approximate Cost	Monitoring Level (see Appendix 9)	Organizations Using Method
Estimate using float and cross sectional area, length, and velocity	Negligible (most items needed for this method can be found at home)	I	None known
Flow Meters	\$300-\$1500	I	- Loudoun Soil and Water Conservation District

Chapter 16

Visual Stream Assessments (Stream Walks)

What is a Visual Stream Assessment?

A visual stream assessment is basically a “stream walk” to evaluate stream health by assessing the physical habitat and potential impacts along a stream channel. A stream walk may be done on foot or by using a boat or canoe depending on the stream.

Why Conduct a Stream Walk?

Conducting a stream walk can produce valuable information about your stream. You may wish to conduct a stream walk prior to water quality monitoring to determine where to focus monitoring efforts. A stream walk may be performed in conjunction with water quality monitoring to help you formulate some theories about what may be impacting the monitoring data. Some stream walks may be conducted to determine potential impacts on stream health with no plans of monitoring.

How Can You Use the Information from a Stream Walk?

Stream walks may collect qualitative (such as rating erosion) or quantitative (such as mapping pipe outfalls) information which will ultimately determine the use of the information gathered. This information can be used to establish baseline conditions and then later stream walks can document changes over time. Some organizations may use the information to determine areas where best management practices (BMPs) are needed. BMPs are pollution control techniques used to reduce pollution from agriculture, timbering practices, construction, marinas, and stormwater. For impaired streams, the stream walk information may be useful background information for developing Total Maximum Daily Load (TMDL) Plans and TMDL Implementation Plans.

How Do You Conduct a Stream Walk?

There are several methods utilized for conducting stream walks, which are based upon similar elements. These methods often are adapted specifically to the stream and the goals of the organization conducting the stream walk.

The James River Association (JRA) developed a draft *Physical Assessment Guide* based upon a number of methods, including *Streamwalk* (developed by the U. S. Environmental Protection Agency’s (EPA) Regional Office in Seattle, Washington.

For more information on the draft Physical Assessment Guide, please contact the James River Association at 804-730-2898 or <http://www.jamesriverassociation.org>.

In association with the Virginia Save Our Streams Program, JRA is field-testing and revising the guide. The goal of this guide is to develop a method specific for Virginia that can be adapted as needed by anyone interested in conducting a stream walk. This method is primarily a visual observation of stream habitat and physical attributes.

Other methods used in Virginia include: a protocol used by the Mattaponi and Pamunkey Rivers Association (contact information is in Appendix 1) based on a Maryland Department of Natural Resources protocol and a U. S. Department of Agriculture (USDA) protocol¹. In general, stream walk protocols require that you walk, canoe, or boat along a defined stretch of stream while observing water and land conditions, land and water uses, potential pollution problems and changes over time. These observations typically are photographed and recorded on maps and data sheets.

¹ U. S. Department of Agriculture. 1998. *National Water and Climate Center Technical Note 99-1: Stream Visual Assessment Protocol*. December.

Chapter 17

Riparian Forests and Stream Health

This chapter has been excerpted and adapted, with permission, from Austin, Samuel H. 1999. *Riparian Forest Handbook 1*, Virginia Department of Forestry, December.

What is a Riparian Forest and Why is it Important?

A riparian forest is simply a streamside forest. The benefits of riparian forests are numerous, from protecting the physical stream environment to removing or transforming nutrients, sediments and pollutants. Overall, riparian forests lead to improved water quality.

Riparian forests protect the physical stream environment in a number of ways:

- Riparian forests help reduce fluctuations in water temperature and regulate light levels reaching a stream resulting in a more stable habitat for plant and animal life.
- Riparian forests provide woody debris for increased habitat diversity for benthic macroinvertebrates and fish.
- Leaf litter and algal (microscopic plant) production, the two primary sources of food energy inputs to streams, are intimately tied to the presence of riparian forests. Studies show that the algal community of a stream well-shaded by older trees is dominated by single-celled algae (diatoms) throughout the year. Streams in deforested areas often contain many thread-like (filamentous) green algae, and few diatoms. While some macroinvertebrates such as crayfish readily consume filamentous green algae, most herbivorous species of stream macroinvertebrates have evolved mouth parts specialized for scraping diatoms from the hard surfaces and cannot eat filamentous algae. Streamside deforestation is one factor that can cause macroinvertebrate diversity to decline.
- Absence of a streamside forest can change channel morphology (the dimension, pattern, and profile of a channel) resulting in habitat loss.

Healthy forest streams have a stable dimension, pattern, and profile that fit the natural landform of the surrounding landscape. Stable natural channels tend to be sinuous and relatively narrow with little exposed or eroding stream bank. They also have access to an active flood plain. Without trees, stream banks may erode creating an unnaturally wide channel. Water velocities may increase as water moves without woody debris to absorb the energy. Faster water combined with altered channel shape can cause bank scour, stream straightening, and excess sediment deposition in the streambed. Each of these can create a degraded environment that supports fewer aquatic plant and animal species.



Eroded stream bank (photo courtesy of Alliance for the Chesapeake Bay).

Stream systems are dynamic, but the change in stable stream systems occurs very slowly within the context of the landscape. Throughout history, humans altered the landscape causing profound effects on the landscape, streams, and rivers. Sections of streams and rivers within many watersheds shifted from a stable geometry to an unstable geometry. These adjustments

continue today. The effects of human activity within the watershed are pronounced and visible on the landscape. As land is cleared, a cycle of events evolves that continues to degrade the stream system.

Why Evaluate Riparian Forests?

Evaluation of your stream's riparian forest may require additional training and technical expertise. However, this activity may be particularly rewarding for volunteer organizations interested in taking water quality monitoring to another level - restoration.

How Can You Use the Information from Your Evaluation?

The Virginia Department of Forestry (DOF) developed *Riparian Forest Handbook 1* along with a companion computer disk to guide you in evaluating a portion of a stream that you may wish to restore. There are regulations and permits required in most localities that pertain to stream restoration. It is strongly recommended that volunteer organizations conduct these evaluations and any restoration work with the assistance of a professional organization, such as a local government or local soil and water conservation district. The computer disk contains programs to assist you in characterizing your stream. Information from your measurements can help you select appropriate restoration activities. Restoration activities include:

The *Riparian Forest Handbook 1* and companion programs may be obtained by contacting the Virginia Department of Forestry at (434) 977-6555.

- Exclusion: Limiting activity near the stream, such as fencing out livestock.
- Planting: Establishing trees along the bank of a stream.
- Channel Modification: Changing the shape of the channel to restore its natural meander, width and depth.

How Do You Evaluate Riparian Forests?

The aforementioned handbook and companion computer disk provide a detailed methodology to evaluate a riparian forest. For evaluating riparian forests, the handbook describes how to measure the departure from desired conditions using three benchmarks (discussed in detail below): the three zone riparian buffer; normal values of stream dimension, pattern, and profile; and normal values of stream particle size and distribution. In any investigation of the departure from desired conditions, it is important that measurements are made and compared for all three benchmarks.

First, select a stream area to evaluate while considering the questions in Chapter 1. As with conducting water quality monitoring, you should research existing information about your stream

before collecting your measurements. Take time to review regional climate data, geology, land types, vegetation, historic land use and any forest plan guidance.

Benchmark 1: Streamside Vegetation in the 3 Zone Riparian Buffer

The 3 zone riparian buffer is an accepted minimum standard for vegetation adjacent to streams and rivers. The area immediately adjacent to the stream (Zone 1) should be comprised of larger woody plants and trees. The roots of this vegetation provide structural support for the stream bank. Zone 2 (the next 60 feet beyond Zone 1) should be a contiguous forest to filter sediments and nutrients from runoff. Beyond Zone 2 should be an area of contiguous forest, perennial grasses, or non-woody plants. To evaluate this benchmark, you will determine the dominant type of plant cover and the density of that cover.

Benchmark 2: Stream Channel Dimension, Pattern, and Profile

Measurements of stream dimension (shape of stream when viewed in cross-section), pattern (shape of stream when viewed from above), and profile (shape of stream when viewed from the “side” along its gradient, i.e. pools and riffles) are used to determine if a stream has a stable “hydrology” and “geology.” A stable stream migrates slowly across its valley over thousands of years. Having evolved slowly in an undisturbed landscape, the dimension, pattern, profile, and water regime of a stream achieve a dynamic equilibrium within the surrounding environment. This equilibrium is an integration of the landscape and historic rainfall patterns upstream.

The first step is to determine hydraulic geometry by measuring a cross-section and a longitudinal profile of the stream channel, using surveying equipment. Calculations based upon these measurements (the software for the *Riparian Forest Handbook 1* includes a program that makes the calculations) are used to categorize the stream according to the Rosgen stream classification system. This classification system is commonly used to group streams with similar configurations.

Benchmark 3: Stream Channel Particle Size Distribution

In addition to streamside vegetation and hydraulic geometry, the sediment load of a stream is a useful benchmark of stability. As a stream system evolves over time, it develops a characteristic set of sediment particle sizes in the streambed. These particles move through the channel over time. The quantities of each size of material depend on the geology of the watershed and the energy of water flow in the system. In an undisturbed stream system, the distribution of particle sizes indicates the natural sediment load of the streambed (known as “bed load”). Any abrupt change in vegetation, land surface features, or length, width, depth and shape of portions of the stream channel can cause streams to adjust to recapture a stable shape. A frequent consequence of these adjustments is a shift away from the normal sediment particle size distribution. A pebble count (where particles are selected and measured) is typically used to determine particle size distribution.

Appendices



Photo Courtesy of Virginia Save Our Streams

Appendix 1

Contacts

Virginia Citizen Water Quality Monitoring Program Contacts

Alliance for the Chesapeake Bay
<http://www.AllianceChesBay.org>
smoulds@acb-online.org
(804) 775-0951
PO Box 1981
Richmond, VA 23218

Virginia Department of Environmental Quality
<http://www.deq.state.va.us/cmonitor>
jfbrooks@deq.state.va.us
(804) 698-4000 or toll free in Virginia (800)
592-5482
P.O. Box 10009
Richmond, VA 23240

Virginia Department of Conservation &
Recreation
<http://www.dcr.state.va.us>
203 Governor St., Suite 206
Richmond, VA 23219

Virginia Save Our Streams Program
<http://vasos.org>
vasosoffice@vasos.org
(540) 377-6179/toll free (888) 656-6664
7598 North Lee Highway
Raphine, VA 24472

Other Contacts Mentioned in Manual

Appomattox River Water Quality
Monitoring Program
Clean Virginia Waterways
Longwood University
<http://web.lwc.edu/cleanva/>
Cleanva@longwood.edu
(434) 395-2602
Dept. of Natural Sciences
Farmville, VA 23909

Ferrum College
Smith Mountain Lake and Claytor Lake
Water Quality Monitoring Programs
[http://www.ferrum.edu/waterqual/sml/index](http://www.ferrum.edu/waterqual/sml/index.htm)
[.htm](mailto:djohnson@ferrum.edu)
djohnson@ferrum.edu
Ferrum, VA

Assateague Coastal Trust
<http://www.actforbays.org>
mail@actforbays.org
(410) 629-1538
Box 731
Berlin, MD 21811

Friends of Powhatan Creek Watershed
<http://www.widomaker.com/~watershed>
watershed@widomaker.com
403 Neck O'Land Road
Williamsburg, VA 23185

Audubon Naturalist Society
[http://www.audubonnaturalist.org/](http://www.audubonnaturalist.org/rustsanct.htm)
[rustsanct.htm](http://www.audubonnaturalist.org/rustsanct.htm)
(703) 803-8400
Web Sanctuary
P.O. Box 51
Clifton, VA 22207

Friends of the Shenandoah River
<http://www.fosr.org>
kanderse@su.edu
(540) 665-1286
Shenandoah University
1460 University Drive (Gregory Hall)
Winchester, VA 22601

James River Association
<http://www.jamesriverassociation.org>
keeper@jamesriverassociation.org
(804) 730-2898
P.O. Box 909
Mechanicsville, VA 23111

Lake Anna Civic Association
[http://www.lakeannavirginia.org/
WaterQuality.htm](http://www.lakeannavirginia.org/WaterQuality.htm)
P.O. Box 217
Lake Anna, VA 23117-0217

Loudoun Soil & Water Conservation
District
<http://www.loudoun.vaswcd.org>
loudoun-swcd@va.nacdnet.org
30 Catocin Circle, S.E., Suite H
Leesburg, VA 20175
(703) 777-2075

Loudoun Wildlife Conservancy
<http://www.loudounwildlife.org>
P.O. Box 2088
Purcellville, VA 20132-2088

Mattaponi and Pamunkey Rivers Association
<http://www.mpra.org>
(804) 769-0841
P.O. Box 157
Walkerton, VA 23177

Northern VA Soil & Water Conservation District
<http://mason.gmu.edu/~jarcisze/StreamMonitoring>
jarcisze@gmu.edu
(703) 324-1425
12055 Government Center Pkwy #905
Fairfax, VA 22035-5512

Upper Rappahannock Watershed Stream
Monitoring Program
<http://www.rappmonitor.va.nacdnet.org>
rappmonitor@yahoo.com
(540) 937-3934

Appendix 2

Letter of Agreement

Letter of Agreement to Implement the Virginia Citizen Water Quality Monitoring Program

The Alliance for the Chesapeake Bay;
The Virginia Department of Conservation and Recreation;
The Virginia Department of Environmental Quality; and
The Virginia Division Izaak Walton League of America,
Virginia Save Our Streams Program

Purpose

The Alliance for the Chesapeake Bay (ACB); the Virginia Department of Conservation and Recreation (DCR); the Virginia Department of Environmental Quality (DEQ); and the Virginia Division Izaak Walton League of America, Virginia Save Our Streams Program (IWLA VA SOS) are dedicated to supporting the Virginia Citizen Water Quality Monitoring Program throughout the Commonwealth for the purpose of collecting useful water quality information and encouraging environmental stewardship. We recognize that cooperative efforts enhance Virginia's ability to protect and restore the Commonwealth's water quality while also strengthening citizen commitments to water quality issues on a local level. While many government agencies and other organizations participate in and support this cooperative effort, this Letter of Agreement defines the roles of the agencies, ACB, and the IWLA VA SOS in the implementation of the Virginia Citizen Water Quality Monitoring Program. We have entered into this agreement with the understanding that combined efforts are less duplicative and can produce greater and more consistent benefits for the common good.

Goals

Support Citizen Water Quality Monitoring Efforts Statewide:

We will work to support the Citizens for Water Quality (CWQ), a statewide consortium of citizen groups, agency representatives, businesses, and individuals interested in preserving and enhancing Virginia's water resources. We will facilitate communication among citizen water quality monitoring groups across Virginia, as well as communication between those groups and state agencies. We will participate in the Virginia Water Monitoring Council. We will provide and support training opportunities on water quality issues. We will continue to identify new partnerships and funding sources to support existing monitoring groups and stimulate new ones.

Promote Appropriate Quality Assurance and Quality Control:

We will identify appropriate water quality sampling protocols, publish the protocols in the Virginia citizens monitoring methods manual, and provide training on these protocols. We will develop a collaborative strategy to promote the need for and the development of quality assurance project plans in accordance with data use goals. We will provide guidance and support to citizen water quality monitoring groups in the development of quality assurance project plans.

Promote the Use of Citizen Water Quality Data in Virginia:

We will promote the use of citizen water quality data as described in the section titled, “Citizen Data in Virginia.” We will include citizen water quality data in water quality assessments as appropriate. We will seek appropriate new uses for citizen-generated water quality data in Virginia.

Promote Partnership and Collaboration Among Citizen Water Quality Monitoring Efforts:

We will promote collaboration among organizations involved in citizen water quality monitoring efforts. We will work to expand and support existing partnerships and build new relationships. We will seek opportunities to improve dissemination of information and increase involvement in environmental stewardship activities.

Signatory Responsibilities

Alliance for the Chesapeake Bay

ACB will continue to provide training to citizen monitors in water quality monitoring methods, provide quality assurance oversight for participating volunteers and assist in identifying new opportunities for citizen stewardship activities. ACB will continue to promote citizen stewardship efforts and will assist in locating citizens and citizen organizations desiring to participate in citizen water quality monitoring and related activities. ACB will assist organizations in identifying sources of funding and organization development.

Virginia Department of Conservation and Recreation

As part of the Department’s statewide responsibilities, DCR will provide technical expertise and general information on matters concerning nonpoint source pollution. In cooperation with DEQ, DCR will provide technical expertise and general information on Total Maximum Daily Load development. DCR will provide technical expertise and general information on planning citizen water quality monitoring programs. DCR will promote the use of citizen data to meet the Commonwealth’s water quality data needs and will assist in identifying appropriate uses for citizen-generated data. DCR will promote the delivery of citizen stewardship activities on a watershed basis and will work to identify new opportunities for citizen stewardship efforts. DCR will work to engage citizens and citizen organizations in water quality monitoring and related stewardship activities. DCR will continue to provide technical expertise and general information on grant writing, sources of funding, public outreach techniques, organization development, and marketing.

Virginia Department of Environmental Quality

As part of the Department’s statewide responsibilities, DEQ will provide technical expertise and general information on matters concerning point source pollution. In cooperation with DCR, DEQ will provide technical expertise and general information on Total Maximum Daily Load development. DEQ will continue to provide technical expertise and general information about monitoring water quality including monitoring protocols, planning water quality monitoring programs, existing agency monitoring locations, site selection, data management, and quality assurance and quality control measures. DEQ will maintain the Virginia citizens monitoring methods manual and may provide citizen water quality monitoring grants to support citizen efforts. DEQ will promote the use of citizen data to meet the Commonwealth’s water quality

data needs and will assist in identifying appropriate uses for citizen-generated data. DEQ will continue to assist in identifying new opportunities for citizen stewardship efforts.

IWLA Virginia Save Our Streams

IWLA VA SOS will continue to provide training to citizen monitors in water quality monitoring methods, provide quality assurance oversight for participating volunteers and assist in identifying new opportunities for citizen stewardship activities. IWLA VA SOS will continue to promote citizen stewardship efforts and will assist in locating citizens and citizen organizations desiring to participate in citizen water quality monitoring and related activities. IWLA VA SOS will assist organizations in identifying sources of funding and organization development.

Citizen Water Quality Data in Virginia

We recognize that citizen water quality data has many uses in Virginia depending on the needs of the citizen monitoring group, the type of monitoring protocols used, and the completeness of the monitoring quality assurance project plan. We further recognize that the use of citizen water quality data as evidence in enforcement actions is not appropriate.

Education

Citizen water quality monitoring data can be used both in a classroom setting and as an educational tool for community members. In the classroom, monitoring activities instruct students about the scientific method, water quality indicators, and water pollution. In the community, citizen water quality monitoring connects interested citizens to the local water quality conditions. It provides a framework for understanding diverse sources and types of degradation and the benefits of best management practices (BMPs).

Baseline Information

Citizen water quality monitoring data, including chemical, biological, and physical, can be used to establish background conditions and prioritize monitoring needs. The most useful data is collected in association with a quality assurance project plan.

Local Land Use Decisions

Citizen-generated data can contribute to local land use decisions in practical ways. Data can document existing conditions and support the local decision-making process. Similarly, citizen-generated data can document water quality improvements resulting from local actions such as implementation of BMPs.

Red Flag for Pollution Events

Citizen-generated data that indicates unusual conditions for the site can be an indicator of changes in land or resource management that are affecting local water quality. Citizen water quality monitoring can identify initial changes in resource management that can affect water quality as well as acute water quality conditions such as toxic events.

Special Studies

Citizen water quality monitoring data can be used to document water quality improvement projects and short term, special projects.

Assessment Information

Citizen water quality monitoring data collected under DEQ-approved quality assurance project plans are used by DEQ in statewide water quality assessment reports. This data is included in the 305(b) Water Quality Assessment Report and may be included on the Virginia Impaired Waters List.

Period of Performance

This Letter of Agreement continues the collaborative partnership begun in 1998 and reaffirmed in the 1999 Letter of Agreement among DEQ, DCR and IWLA VA SOS. The Virginia Citizen Water Quality Monitoring Program continues to evolve to meet the needs of the Commonwealth and, in this light, ACB is joining as a new signatory to the agreement. This document reflects the signatories' plan for cooperative efforts and should not be construed as a binding contract. Any party may leave this cooperative program at any time and for any reason. Performance of this agreement will continue for a period of 24 months, at which time the agreement will be reviewed and renewed, upon mutual agreement of the signatories.

Nothing in this agreement prohibits ACB, DCR, DEQ, or the IWLA VA SOS from entering into similar agreements with other organizations. Nothing in this agreement prohibits ACB, DCR, DEQ, or the IWLA VA SOS from implementing other programs for which they are responsible. Additional parties may be added to this agreement upon the mutual consent of the signatories.

We, hereby, agree to the conditions described herein:

Alliance for the Chesapeake Bay

By:

Title: David B. Bancroft, Executive Director
Alliance for the Chesapeake Bay

Date:

**Virginia Department of Environmental
Quality**

By:

Title: Robert G. Burnley, Director, Virginia
Department of Environmental Quality

Date:

**Virginia Department of Conservation and
Recreation**

By:

Title: Joseph H. Maroon, Director, Virginia
Department of Conservation and Recreation

Date:

Izaak Walton League of America

By:

Title: Jay Gilliam, Virginia Save Our
Streams Coordinator

Date:

By:

Title: Jay Bolton, President, Virginia
Division Izaak Walton League of America

Date:

Appendix 3

Legislation Establishing the Virginia Citizen Water Quality Monitoring Program in the *Code of Virginia*

Legislation Establishing the Virginia Citizen Water Quality Monitoring Program in the *Code of Virginia*

HB497 Text as Enacted by the General Assembly of Virginia

Code of Virginia §62.1-44.19:11. Citizen water quality monitoring program

The Department of Environmental Quality shall establish a citizen water quality monitoring program to provide technical assistance and may provide grants to support citizen water quality monitoring groups if (i) the monitoring is done pursuant to a memorandum of agreement with the Department, (ii) the project or activity is consistent with the Department of Environmental Quality's water monitoring program, (iii) the monitoring is conducted in a manner consistent with the Virginia Citizens Monitoring Methods Manual, and (iv) the location of the water quality monitoring activity is part of the water quality control plan required under § 62.1-44.19:5. The results of such citizen monitoring shall not be used as evidence in any enforcement action.

Appendix 4

Template for Submittal of Citizen Monitoring Data to the Virginia Department of Environmental Quality

Instructions for Submittal of Citizen Monitoring Data to the Virginia Department of Environmental Quality (DEQ)

1. All data should be submitted electronically in an Excel spreadsheet or compatible format using the appropriate attached template (for chemical or macroinvertebrate monitoring).
2. All data should be included in one worksheet. Each monitoring event (site, date, time) should be entered in a separate line of the data file.
3. Use the attached template without moving or deleting columns. If you do not monitor one or more of the basic parameters included in the attached template, please leave the associated columns blank. If you need to add columns for additional parameters, please do so on the right hand side of the spreadsheet.
4. Major Watershed: Indicate the major river basin where the site is located. Use the following major river basin identifications: (1) Shenandoah/Potomac, (2) James, (3) Rappahannock, (4) Roanoke, (5) Chowan River/Dismal Swamp, (6) Tennessee/Big Sandy, (7) Chesapeake Bay and Small Coastal Basins, (8) York, and (9) New.
5. Stream Name: Indicate the name of the stream that the station is actually located on, as identified from a USGS topographic map or other standard reference. If the site is on an unnamed tributary to a named stream, please state “Unnamed tributary to (*insert name of stream*)”.
6. Station Number: This number should be unique for each station monitored by a specific citizen or citizens’ group. The station number for a station should not change from one sampling event or data submittal to another.
7. DEQ ID Number: This number will be assigned by DEQ. Once a DEQ ID Number is assigned for a station, it should be included in all subsequent data submittals to DEQ to facilitate data use by the agency.
8. Station Location Description: Include a detailed station location description, so the station can be located on a map (*e.g.*, Rt. 619 bridge or 0.5 miles downstream of Rt. 619 bridge).
9. County: Indicate county where station is located.
10. Latitude/Longitude: If station lat/long is in degrees/minutes/seconds, enter these units in the appropriate columns and leave the decimal degrees columns blank. If lat/long is in decimal degrees, enter these units in the appropriate columns and leave the degrees/minutes/seconds columns blank.
11. Collection Date: Indicate data sample collected in MM/DD/YY format
12. Collection Time: Indicate time sample was collected. If time of collection is not part of your normal data record, you may leave this column blank.

13. Water Temperature: If water temperature is measured, enter the value in this column. If this parameter is not measured, leave column blank. Indicate units (°F or °C) in the parentheses of the field name, but do not include units beside each value. Do NOT enter anything other than numbers (or a negative sign if needed) in this column. If any additional information about the specific value is required (e.g., <, ≤, >, ≥, ±, etc.), describe the value and parameter in the “Comments” column.
14. pH: If pH is measured, enter the value in this column. If this parameter is not measured, leave column blank. Do NOT enter anything other than numbers in this column. Additional information about the specific value should be entered in the “Comments” column.
15. Dissolved Oxygen (DO): If DO is measured, enter the value in this column. If this parameter is not measured, leave column blank. Do NOT enter anything other than numbers in this column. If any additional information about the specific value is required (e.g., <, ≤, >, ≥, ±, etc.), describe the value and parameter in the “Comments” column.
16. Comments: If you need to enter any additional information about the sampling event or any of the values obtained, please do so here. For example, stream conditions (dry, low, normal, flood, etc.), weather (clear, overcast, heavy clouds, raining, etc.) and wind (calm, breezy, windy, etc.) are often very useful in interpreting monitoring data.

Citizen Monitoring Macroinvertebrate Data Submittal Template

Major River Basin	Stream Name	Station #	DEQ Station ID	Station Location Description	County	Latitude Degrees	Latitude Minutes	Latitude Seconds	Longitude Degrees	Longitude Minutes	Longitude Seconds
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Latitude Decimal Degrees	Longitude Decimal Degrees	Collection Date (mm/dd/yy)	Collection Time (24hr – xx:xx)	Water Temperature Value (Units)	Stream Quality Rating	(Organism Name) Count	Comments	Etc.
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Citizen Monitoring Chemical Data Submittal Template

Major River Basin	Stream Name	Station Number	DEQ Station ID	Station Location Description	County	Latitude Degrees	Latitude Minutes	Latitude Seconds	Longitude Degrees	Longitude Minutes	Longitude Seconds
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Latitude Decimal Degrees	Longitude Decimal Degrees	Collection Date (mm/dd/yy)	Collection Time (24hr - xx:xx)	Water Temperature Value (Units)	pH Value (Standard Units)	Dissolved Oxygen Value (Units)	Comments	Additional Parameter (name) Value	Etc.
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Appendix 5

Boilerplate Memorandum of Agreement

**Memorandum of Agreement to Support the Virginia Citizen Water Quality
Monitoring Program Between the Virginia Department Of Environmental
Quality and
ORGANIZATION NAME**

A. Purpose

The Virginia Department of Environmental Quality (DEQ) and ORGANIZATION NAME are dedicated to supporting the Virginia Citizen Water Quality Monitoring Program for the purpose of collecting useful water quality information and encouraging environmental stewardship. We recognize that cooperative efforts enhance Virginia's ability to monitor, assess, protect and restore the Commonwealth's water quality while also strengthening citizen commitments to water quality issues. We have entered into this agreement with the understanding that combined efforts will produce greater and more consistent benefits by more effectively utilizing the resources of the DEQ and ORGANIZATION NAME and eliminating duplication of effort.

B. Background

In the 2002 General Assembly Session, legislation was introduced and passed (§62.1-44.19:11 of the Code of Virginia) which gave DEQ the authority to provide grants to support citizen water quality monitoring groups if (i) the monitoring is done pursuant to a memorandum of agreement with the Department, (ii) the project or activity is consistent with the Department of Environmental Quality's water quality monitoring program, (iii) the monitoring is conducted in a manner consistent with the Virginia Citizens Monitoring Methods Manual, and (iv) the location of the water quality monitoring activity is part of the water quality control plan required under the Code of Virginia. This legislation also prohibits the use of citizen data as evidence in any enforcement actions.

[Customize the paragraph below for the organization]

ORGANIZATION NAME has been committed to protecting the natural resources of STREAM NAME OR WATERSHED NAME. ORGANIZATION NAME has collected water quality data over the past NUMBER years. In keeping with this commitment to protecting the natural resources of the STREAM NAME OR WATERSHED NAME, ORGANIZATION NAME is entering into this agreement with DEQ.

C. Signatory Responsibilities

Virginia Department of Environmental Quality

Since a goal of the Virginia Citizen Water Quality Monitoring Program is to produce citizen water quality data that can be used by DEQ for water quality assessments, DEQ will provide technical expertise to assist ORGANIZATION NAME in meeting this goal. DEQ will continue to provide technical expertise and general information about monitoring water quality including monitoring protocols, planning water quality monitoring programs, existing agency monitoring locations, site selection, data management, and quality assurance and quality control measures. DEQ will maintain a Virginia citizen monitoring methods manual. DEQ will promote the use of

citizen water quality data to meet the Commonwealth's water quality data needs and will assist in identifying appropriate uses for citizen data. DEQ will continue to assist in identifying new opportunities for citizen stewardship efforts. As part of DEQ's statewide responsibilities, DEQ will provide technical expertise and general information on matters concerning point source pollution and Total Maximum Daily Load development.

ORGANIZATION NAME [Customize the paragraph below for the organization]

ORGANIZATION NAME will adhere to the Quality Assurance Project Plan developed by ORGANIZATION NAME and provide citizen water quality data for the watershed that can be used by DEQ for water quality assessments. ORGANIZATION NAME will be responsible for ensuring that their citizen monitors are properly trained, providing quality assurance oversight for participating volunteers, recruiting volunteers as necessary, and identifying new opportunities for citizen stewardship activities. ORGANIZATION NAME will use the water quality data collected for educational purposes and to assist with local land use decisions

D. Monitoring Objectives [Customize the paragraph below for the organization]

We recognize that cooperative efforts enhance Virginia's ability to monitor, assess, protect and restore the Commonwealth's water resources. To reduce duplication of efforts and to produce data that will be useful for water quality assessments, ORGANIZATION NAME will collect data that is consistent with DEQ's water quality monitoring programs. We recognize the need to coordinate water quality monitoring efforts in a collaborative effort to increase the quality and efficiency

E. Quality Assurance Project Plans [Customize the paragraph below for the organization]

The protocols used by ORGANIZATION NAME will be consistent with a revised Virginia citizen monitoring methods manual. ORGANIZATION NAME will select protocols appropriate for the goals of the program with DEQ's assistance. A Quality Assurance Project Plan, developed by ORGANIZATION NAME, documenting the procedures that ORGANIZATION NAME will use for water quality monitoring will be submitted by the end of the first year of this agreement for approval by DEQ.

F. Monitoring Locations [Customize the paragraph below for the organization]

We agree to share monitoring locations in an effort to reduce duplication of efforts and produce data that will be useful for water quality assessments. ORGANIZATION NAME should also consult the Virginia Water Monitoring Council website at <http://www.vwnc.vt.edu/vwmc> for information on other water quality monitoring activities in the watershed.

G. Period of Performance

The Virginia Citizen Water Quality Monitoring Program continues to evolve to meet the needs of the Commonwealth. This document reflects the signatories' plan for cooperative efforts and should not be construed as a binding contract. Either party may leave this cooperative program at any time and for any reason. Performance of this agreement will continue for a period of 24 months, at which time the agreement will be reviewed and renewed, upon mutual agreement of the signatories.

Nothing in this agreement prohibits DEQ, or ORGANIZATION NAME from entering into similar agreements with other organizations. Nothing in this agreement prohibits DEQ or ORGANIZATION NAME from implementing other programs for which they are responsible. Additional parties may be added to this agreement upon the mutual consent of the signatories.

H. Grant Agreement

If ORGANIZATION NAME receives any sources of funding through the Commonwealth, a separate grant agreement with a workplan containing deliverables will be executed.

We, hereby, agree to the conditions described herein:

ORGANIZATION NAME

By:

Title:

Date:

**Virginia Department of Environmental
Quality**

By:

Title: Robert G. Burnley, Director, Virginia
Department of Environmental Quality

Date:

Appendix 6

Virginia Citizens for Water Quality List Serve

Virginia Citizens for Water Quality List Serve

To sign up, send a message to
maiser@lsv.dcr.state.va.us

Then in the body of the text put the following message AND NOTHING ELSE!
SUBSCRIBE vacwqlist

Use the CWQ list serve to share water quality stories, information about events, post questions, etc. Details about the list serve and the guidelines for the list serve are below my signature block.

If you have questions, comments, problems, please let me know!

Introduction to the Citizens for Water Quality (CWQ) List-Serve

The CWQ eMailing List is managed by the web team at the Virginia Department of Conservation and Recreation (DCR) to facilitate information exchange, communication, and group discussion related to water quality issues in Virginia.

CWQ and DCR endorse a policy of free access to the CWQ Mailing List and public dissemination of information communicated through the CWQ Mailing List.

People who are interested in information exchanges and discussions and accept the following Guidelines are welcome to use the CWQ Mailing List service.

How to Join and Leave the CWQ Mailing List

To subscribe to the CWQ List-Serve, send an email message to: <maiser@lsv.dcr.state.va.us>. Please note that the < and > signs should not be included in the E-Mail address or message. These signs are just used to indicate that anything outside the signs should not be included in the address.

The subject of the message doesn't matter, but in the message itself should be the instruction SUBSCRIBE vacwqlist

Anything else in the message will be ignored.

By initiating subscription to the CWQ Mailing List it is understood that the subscriber knows the functioning of the CWQ Mailing List as described here. The subscriber confirms that he or she has read the Guidelines, agrees with it, and will abide by its content.

To remove your address from the CWQ List-Serve, please send an E-Mail message to the same address as above, with the instruction UNSUBSCRIBE vacwqlist in the body of the message.

PLEASE DO NOT SEND REMOVAL MESSAGES TO THE CWQ MAILING LIST! The list server software will ignore those requests.

It is possible to specify that messages be sent to the user in a digest format (that is, all of the messages for a day are gathered together and sent at once to the user, rather than each message as it comes in), as well as other options. To get a full list of list server commands, send a message to the address above, with the instruction HELP as the body of the message. A help file will be returned describing all mailing list options.

Posting Messages

To post an email message on the CWQ List-Serve after you have signed up, send your message to the following address: <vacwqlist@lsv.dcr.state.va.us>. Messages posted to the CWQ List-Serve will be forwarded to all currently registered subscribers of the CWQ List-Serve. Messages sent to the CWQ List-Serve are stored and included in the CWQ List-Serve Archives, which will be available soon.

Replying to Messages

To reply to a message posted on the CWQ List-Serve use the Reply to: or Answer feature of your email program. Since some mail programs may not use the reply-to address included in a mail message, make sure that the reply is addressed to vacwqlist@lsv.dcr.state.va.us. Your reply message will be distributed to all CWQ List-Serve subscribers. Please note that a reply message intended only for the originator of the message may also be sent to all CWQ List-Serve subscribers.

To avoid public dissemination of such a message and in order to protect the entire CWQ List-Serve subscriber community from irrelevant messages, please do not use the reply function of your e-mail service. Instead, generate a new email message to the intended recipient.

Monitoring, Publication, and Storage of Messages

The CWQ List-Serve aims to provide a freely accessible and open communication forum that facilitates discussion and sharing of experience in the field of water quality issues in Virginia. The CWQ List-Serve therefore adheres to the principle of free speech and stresses individual responsibility for statements communicated through it.

Furthermore, users who repeatedly violate the Protocol are subject to cancellation of their subscription upon appropriate warning by the CWQ List-Serve.

The CWQ List-Serve Archive is meant for public access and reference. The CWQ advises its List-Serve subscribers that even after users delete an email message from their computers or email accounts it may remain in the Archive or other backup facilities and thus is subject to public disclosure. Details about the archive will come at a later point

Citizens for Water Quality List-Serve Guidelines

List serves or electronic mailing lists are one of the most useful means of communication, since they enable their members to instantly transmit or receive information and opinions on matters of common interest. When a message is sent to an electronic mailing list the list server immediately distributes it to all subscribers. Conversely, when replies to that message are emailed; they too, are broadcast to the entire list of subscribers in a matter of minutes or seconds, making this a highly interactive form of communication.

The following suggested guidelines are intended to make the electronic mailing lists valuable and productive for all subscribers.

1. Keep a Copy of the Welcome Letter When you successfully sign-up with the CWQ List-

Serve, you will receive a welcome message. This letter will contain tips for sending your mail as well as how to unsubscribe from that mailing list. You should store this message either on your computer or print a hard copy.

2. **Following Threads of Discussions** By signing up with the CWQ List-Serve, you are not obligated to respond to all messages, or to any message. Pick and choose the topics that interest you. Look at the subject line of the incoming messages to see which thread of discussion is being addressed in that message.

3. **Help When You Can** The purpose of the CWQ List-Serve is to share information. Help individuals in a query whenever you can, because someday you may want help locating information. Sometimes it is better to respond to just an individual rather than sending your message to the entire CWQ List-Serve group.

4. **Unsubscribe If You'll Be Gone** If you plan on being gone for more than a week and will be unable to check your e-mail, you should unsubscribe from the list then you can resubscribe when you return.

5. **Use a Meaningful Subject Line** When people receive mail from a listserv, one of the first pieces of information they look at is the subject line. Most people will keep the same subject line when they respond to a particular thread of discussion. Some people will delete unread messages simply because the subject line announces a topic that they are not interested in. This saves time for many people.

6. **Sending Attachments** Never send attachments with e-mail messages to individuals or to the CWQ List-Serve without prior permission from the recipient.

7. **Cross Posting** If you are posting the same message to several listserves, at the beginning of your messages state, "This message has been cross posted to (names of other listserves)."

8. **Brevity is important.** Please keep your messages as short and to the point as is consistent with conveying the substance of your thoughts.

9. **Identify yourself.** Please sign your message with your full name and Citizens for Water Quality affiliation. Among other things, this gives your colleagues the opportunity to consult directly with you on questions or issues that may have come up in the discussion.

10. **Be careful with replies.** It is important to remember that all messages and replies posted to the list are sent to the entire list. Consequently, if you wish to transmit something of a more personal or private nature, please send it directly to the recipient rather than through the electronic mailing list. When possible, avoid replies that include prior correspondence since long messages tend to slow the process. Please do not use auto-reply. Electronic mailing lists often include a large number of individuals, which makes auto-replies undesirable. If you will be gone for a period of time, please unsubscribe before you leave and subscribe when you return.

11. **Do not challenge or attack others.** The discussions are meant to stimulate conversation not to create contention. Let others have their say, just as you may. All defamatory, abusive, profane, threatening, offensive, or illegal materials are strictly prohibited. Do not post anything in a discussion group message that you would not want the world to see or that you would not want anyone to know came from you.

12. **Responding to Messages** Only send a message to the entire list when it contains information that everyone can benefit from. Send messages such as "thanks for the information" or "me too" to individuals--not to the entire list. Do this by using your e-mail application's forwarding option and typing in or cutting and pasting in the e-mail address of the individual to whom you want to respond.

13. You could consider prefacing your message with headings like: No Response required; For

Information Only; Urgent Response Required etc.

14. Do not publish jokes circulating in other email lists however funny you think they are. This does not exclude the use of humor!

15. You can ask to be removed temporarily or permanently at any time.

16. Send a message of greeting to the list! This will help give you the hang of it, and prepare you for the day that you want to urgently communicate on a real matter.

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Appendix 7

Resources

Resources

General Citizen Water Quality Monitoring Resources

Campbell, G. and S. Wildberger. 1992. *The Monitor's Handbook*. LaMotte Company, Chestertown, Md. 71 pp.

Center for Marine Conservation & U. S. EPA. *Volunteer Estuary Monitoring: A Methods Manual*, Second Edition. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>

Hach. 1997. *Hach Water Analysis Handbook*. 3rd ed. Hach Company, Loveland CO.

Miller, J.K. 1995. *Program Organizing Guide*. River Watch Program of River Network. Montpelier, VT.

Mitchell, M., and W. Stapp. 1999 *Field Manual for Water Quality Monitoring*. 12th ed. Kendall/Hunt. Available from GREEN, c/o Earth Force, Inc., 1908 Mount Vernon Ave., Alexandria, VA. Web site: <http://www.earthforce.org/green/>

U. S. Environmental Protection Agency (USEPA). 1990. *Volunteer Water Monitoring: A Guide For State Managers*. EPA 440/4-90-010. August. Office of Water, Washington, DC. 78 pp. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>

U. S. Environmental Protection Agency (USEPA), 1991. *Volunteer Lake Monitoring: A Methods Manual*. EPA 4400/4-91-002. Office of Water, Washington, DC. 121 pp. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>

U. S. Environmental Protection Agency (USEPA). 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA841-B-97-003. November. Office of Water, Washington, DC. 211 pp. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>

Web Sites

Chesapeake Bay Program: <http://www.chesapeakebay.net/>

Citizens for Water Quality: <http://www.vasos.org/cwq.htm>

National Oceanic & Atmospheric Administration (NOAA)
National Sea Grant Program: <http://www.nsgo.seagrant.org/index.html>
Volunteering for the Coast: <http://volunteer.nos.noaa.gov/>

U. S. Environmental Protection Agency (EPA)
Surf Your Watershed: <http://www.epa.gov/surf>
Volunteer Monitoring <http://www.epa.gov/owow/monitoring/volunteer/>
Watershed Information Network <http://www.epa.gov/win>

Virginia Department of Conservation and Recreation (DCR)
Adopt-A-Stream: <http://www.dcr.state.va.us/sw/adopt.htm>

Virginia Department of Virginia Department of Environmental Quality (DEQ)
Citizen Monitoring: <http://www.deq.state.va.us/cmonitor/>
DEQ Monitoring Data: <https://www.deq.state.va.us/webapp/wqm.homepage>

Virginia Water Monitoring Council: <http://www.vwrrc.vt.edu/vwmc/>

Newsletters

Coastlines - National Estuary Program Newsletter
Available online at <http://www.epa.gov/nep/coastlines>. Subscriptions are free. To subscribe, contact coastlines@umbsky.cc.umb.edu.

The Volunteer Monitor - National Newsletter of Volunteer Water Quality Monitoring
Available online at http://www.epa.gov/owow/monitoring/volunteer/vm_index.html.
Subscriptions are free. To subscribe, contact skvigil@yahoo.com

List Serves

Citizens for Water Quality List Serve (Virginia Citizen Monitoring List Serve): Please see Appendix 6 for instructions and guidelines for this list serve.

EPA Volunteer Monitoring List Serve (National Citizen Monitoring List Serve):
To subscribe or unsubscribe, send an email to listserv@unixmail.rtpnc.epa.gov. Leave the subject line blank. In the message type:
Subscribe volmonitor lastname firstname or unsubscribe volmonitor lastname firstname
To post a message, address your email to volmonitor@unixmail.rtpnc.epa.gov

Chapter 2: Quality Assurance Project Plans and Approved Methods

American Public Health Association (APHA), American Water Works Association, and Water Environment Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed. L. S. Clesceri, A. E. Greenberg, A.D. Eaton (eds). Washington, DC.

Mattson, M. 1992. "The Basics of Quality Control." *The Volunteer Monitor* 4(2): 6-8.

U. S. Environmental Protection Agency (USEPA). 1996. *The Volunteer Monitor's Guide to Quality Assurance Project Plans*. EPA 841-B-96-003. September. Web site:
<http://www.epa.gov/OWOW/monitoring/volunteer/qappcovr.htm>

Chapter 4: Dissolved Oxygen

Green, L. 1997. "Common Questions About DO Testing." *The Volunteer Monitor* 9(1).

Green, L. 1998. "Let Us Go Down to the Sea-How Monitoring Changes from River to Estuary." *The Volunteer Monitor* 10(2): 1-3.

Chapter 6: Nutrients

Dates, G. 1994. "Monitoring for Phosphorus or How Come They Don't Tell You This Stuff in the Manual?" *The Volunteer Monitor* 6(1).

Katznelson, R. 1997. "Nutrient Test Kits: What Can We Expect?" *The Volunteer Monitor* 9(1).

Chapter 7: Benthic Macroinvertebrates

Engel, Sarah R. and J. Reese Voshell, Jr. 2002. "Volunteer Biological Monitoring: Can It Accurately Assess the Ecological Condition of Streams?" *American Entomologist* 48 (3): 164-177. Web site: <http://www.vasos.org/ValidationStudy.htm>

U. S. Environmental Protection Agency (USEPA). 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers; Periphyton, Benthic Macroinvertebrates and Fish*, second edition, EPA Publication 841-B-99-002. Web site: <http://www.epa.gov/owow/monitoring/rbp>

Web Sites

Virginia Save Our Streams Program: <http://www.sosva.com/>

Chapter 8: Bacteria

Ely, E. 1998. "Bacteria Testing Part 1: Methods Primer." *The Volunteer Monitor* 10(2):8-9

Ely, E. 1998. "Bacteria Testing Part 2: What Methods Do Volunteer Group Use?" *The Volunteer Monitor* 10(2): 10-13.

Ely, E. 1997 "Interpreting Fecal Coliform Data: Tracking Down the Right Sources." *The Volunteer Monitor* 9(2): 18-20

Miceli, G. 1998. "Bacteria Testing Q & A." *The Volunteer Monitor* 10(2): 13-15

Chapter 10: Submerged Aquatic Vegetation (SAV)

U. S. Environmental Protection Agency (USEPA). 2000. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis*. August.

Bergstrom, P. 1998. "SAV Hunter's Guide (for Chesapeake Bay)." *The Volunteer Monitor* 10(2): 17.

Hurley, L. M. 1992. *Field Guide to the Submerged Aquatic Vegetation of the Chesapeake Bay*. U. S. Fish and Wildlife Service Chesapeake Bay Estuary Program. Annapolis, MD. 52PP. (NOTE: Out of print).

Meyers, D. 1999. "Volunteers Add 'Missing Piece': Monitoring Restoration." *The Volunteer Monitor* 11(1): 10-11.

Reshetiloff, K. 1998 "SAV Hunt: Citizens Keep Track of Bay Grasses." *The Volunteer Monitor* 10(2): 16

Web Sites

Alliance for the Chesapeake Bay: <http://www.acb-online.org/projects.cfm>

Chesapeake Bay Foundation: <http://www.savethebay.cbf.org>

Chesapeake Bay Program: <http://www.chesapeakebay.net/baygras.htm>

U. S. Fish and Wildlife Service Chesapeake Bay Field Office:
<http://www.fws.gov/r5cbfo/CBSAV.HTM>

Virginia Institute of Marine Science: <http://www.vims.edu/bio/sav/index.html>

Chapter 15: Stream Flow

Rantz, S.E., and others, 1982, *Measurement and Computation of Streamflow: Volume 2. Computation of Discharge*. U. S. Geological Survey Water-Supply Paper. 2175.

Web Sites

U. S. Geological Survey (USGS): <http://www-va.usgs.gov>

Chapter 16: Stream Walks

U. S. Department of Agriculture. 1998. *National Water and Climate Center Technical Note 99-1: Stream Visual Assessment Protocol*. December.

U. S. Environmental Protection Agency (USEPA). 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA841-B-97-003. November. Office of Water, Washington, DC. 211 pp. Web site <http://www.epa.gov/owow/monitoring/volunteer/>

Chapter 17: Riparian Forests

Austin, Samuel H. 1999. *Riparian Forest Handbook 1*, Virginia Department of Forestry, December.

Appendix 8

Equipment Suppliers

Equipment Suppliers

This is a partial list of common equipment suppliers from which a volunteer monitoring program may obtain equipment for water quality monitoring. This list is intended to assist programs in locating equipment and does not imply endorsement by the Virginia Citizen Water Quality Monitoring Program or any of its partners.

Ben Meadows Company

<http://www.benmeadows.com>

Phone: 800-241-6401

Waders, field water test equipment, nets.

Carolina Biological Supply Company

<http://www.carolina.com>

Phone: 800-334-5551

Forceps, reagents, educational materials.

Cole Parmer Instruments, Inc.

<http://www.coleparmer.com>

Phone: 800-323-4340

Lab equipment, field water test equipment.

Earth Force

<http://www.earthforce.org>

E-mail: green@earthforce.org

Phone: 703-299-9485

Low-cost kits for schools.

Fisher Scientific Company

<http://www.fishersci.com>

Phone: 800-766-7000

Lab equipment, sample bottles, reagents, water test equipment, Whirl-paks.

Forestry Suppliers, Inc.

<http://www.forestry-suppliers.com>

Phone: 800-647-5368

Secchi disks, transparency tubes, equipment.

Hach Equipment Company

<http://www.hach.com>

Phone: 800-227-4224

Field and lab equipment, reagents.

Hydrolab Corporation

<http://www.hydrolab.com>

Phone: 800-949-3766

Multi-parameter meters for water monitoring.

Idexx Laboratories

<http://www.idexx.com/water>

Phone: 800-321-0207

Colilert method for bacterial monitoring.

LaMotte

<http://www.lamotte.com>

Phone: 800-344-3100

Field and lab water testing equipment, Secchi disks, armored thermometers.

Micrology Laboratories

<http://micrologylabs.com>

Phone: 888-EASYGEL

Coliscan Easygel method for bacterial monitoring.

Nichols Net and Twine, Inc.

Phone: 618-797-0222; 800-878-6387

Nets of all kinds (dip, kick, macroinvertebrates), seines, custom nets.

Water Monitoring Equipment & Supply

<http://www.watermonitoringequip.com>

E-mail: info@watermonitoringequip.com

Phone: 207-276-5746

Transparency tubes, monitoring equipment.

YSI Incorporated

<http://www.ysi.com>

Phone: 937-767-7241

Meters for water quality monitoring.

Appendix 9

Monitoring Levels of Citizen Water Quality Data in Virginia

Monitoring Levels of Citizen Water Quality Data in Virginia

In Virginia, three levels of data quality have been developed by the Department of Environmental Quality (DEQ) based upon the use of citizen water quality data by the agency and other data users. Citizen-collected data may be used to educate the community, to assist local governments in land use planning, to supplement data for university and professional studies, and to assist local soil and water conservation districts in prioritizing watershed work for best management practices.

<u>Level</u>	<u>Appropriate Data Uses (refer to Appendix 2)</u>	<u>QA/QC Protocols</u>
I	<ul style="list-style-type: none"> • Education • Baseline • Red Flags • Local Land Use Decisions • Special Studies 	<ul style="list-style-type: none"> • No Quality Assurance Project Plan (QAPP) or SOP required by DEQ. • Uniform methodology recommended. • QAPP, SOPs and/or lab methods do not meet DEQ quality assurance/quality control requirements. • There is no Virginia Water Quality Standard for parameter the method measures.
II	<ul style="list-style-type: none"> • Assessment Information • Education • Baseline • Red Flags • Local Land Use Decisions • Special Studies 	<ul style="list-style-type: none"> • DEQ-approved Quality Assurance Project Plan and SOPs using DEQ-approved methods. • At this level, there may be deviation from an approved method if it can be demonstrated that the method collects data of similar quality to an approved method. • Field and/or laboratory audit required.
III	<ul style="list-style-type: none"> • Impairment, or 303(d), listings • Assessment Information • Education • Baseline • Red Flags • Local Land Use Decisions • Special Studies 	<ul style="list-style-type: none"> • DEQ-approved Quality Assurance Project Plan and SOPs with no deviation from approved methods (i.e., a Standard Method (APHA, 1998) or method approved by the U.S. Environmental Protection Agency). • Field and/or laboratory audit required.

Appendix 10

Monitoring Plan Worksheets

Monitoring Plan Worksheets

(Chapter 1 will guide you with completing these worksheets)

Project Name: _____

Organization Name: _____

Contact Person for Project: _____

Phone Number for Contact: _____

Email Address for Contact: _____

Mailing Address for Contact: _____

Date Monitoring Plan Completed: _____

Step 1: Problem Definition/Background

1. What waterbody(ies) do you want to monitor? _____

2. What monitoring/studies have been conducted in your waterbody of interest? _____

3. Have you consulted the following sources to determine if monitoring data has been collected:

- | | |
|--|--------------------------|
| a. DEQ Water Quality Monitoring Database at
http://www.deq.state.va.us/water/monitoring.html | <input type="checkbox"/> |
| b. VWMC online database at
http://www.vwrrc.vt.edu/vwmc/Survey.asp | <input type="checkbox"/> |
| c. USGS | <input type="checkbox"/> |
| Local governments | <input type="checkbox"/> |
| Local soil and water conservation district | <input type="checkbox"/> |
| College or universities | <input type="checkbox"/> |
| Others? _____ | <input type="checkbox"/> |

Problem statement/issues affecting your watershed? _____

Step 2: Why Are You Monitoring?

A. Overall goals: _____

B. Questions and information needed to address issues

<u>Questions/Issues to Address</u>	<u>Information Needed</u>

Step 3: Intended Uses and Users of Data

List data users and intended use of data. Consult with data users to determine the quality of data they need. For example, if data will be used for screening purposes only, you may not need to use approved methods or follow rigorous quality assurance/quality control checks on the data.

<u>Data User</u>	<u>Data Use</u>	<u>Level of Data Quality Needed</u>

Step 4: Where Will You Monitor?

- A. Are all sites in safe locations on public property or where landowner permission has been obtained? _____

- B. Are all sites representative of the stream (in the main flow of the stream away from discharge pipes)? _____

- C. At what depth will samples be collected? _____

Steps 5 & 6: What Parameters/Conditions Will You Monitor?

Sampling Methods and Analytical Methods Requirements

<u>Parameter</u>	<u>Field or Lab Analysis</u>	<u>Sampling Method (specify lab analysis method number or manufacturer and model # of test kit, meter, or other instrument)</u>	<u>Why Do You Want to Monitor this Parameter?</u>
Bacteria - <i>E. coli</i>			
Bacteria – Fecal Coliform			
Benthic Macroinvertebrates			
Chlorophyll <i>a</i>			
Conductivity			
Dissolved Oxygen			
Flow			
Nitrogen (Identify species)			
pH			
Phosphorus (Identify species)			
Salinity			
Total Solids (specify form)			
Turbidity/ Transparency			
Water Temperature			
Other			
Other			
Other			
Other			
Other			

Step 8: When Will You Sample?

[illegible]

Step 9: Data Management and Reports

- A. What will happen to data sheets once they are completed? _____

- B. What software program will used? _____

- C. Who will enter the data? _____
- D. Who will verify the accuracy of data entry? _____
- E. How will data be analyzed? _____

- F. How will data be communicated to others? _____

Step 10: Quality Assurance/Quality Control

- A. Training Requirements/Certification
1. Who will train volunteers? _____
 2. Describe initial training requirements. _____

 3. Describe refresher training requirements. _____

- B. Is a QAPP needed for intended use of data? _____

If so, these worksheets can be expanded into a formal QAPP (Chapter 2 and Appendix 14)

Appendix 11

**Technical Resource: Excerpt from
EPA *Guidance Specifying
Management Measures for Sources
of Nonpoint Pollution in Coastal
Waters***

In 1990, Congress enacted the Coastal Zone Act Reauthorization Amendments and included a new section titled ‘Protecting coastal waters (Section 6217)’. The program is jointly administered by the National Oceanic & Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA). The purpose of the program is to develop and implement management measures for nonpoint sources of pollution to restore and protect coastal waters. A key element of the program is to work in coordination with other federal, state, and local entities. Each state program is required to develop a program under this section that will ‘provide for the implementation, at a minimum, of management measures in conformity with the guidance published under subsection (g), to protect coastal waters.’

This appendix is intended to provide additional technical resource information to organizations and individuals that conduct water quality monitoring activities. The information has been excerpted from guidance developed by national work groups and released in 1993 by EPA. The full guidance document can be found at <http://www.epa.gov/owow/nps/MMGI/>. EPA has recently released updated individual chapters as ‘national’ management measures. The updates can be found at <http://www.epa.gov/owow/nps/pubs.html>.

II. Techniques for Assessing Water Quality and for Estimating Pollution Loads

Water quality monitoring is the most direct and defensible tool available to evaluate water quality and its response to management and other factors (Coffey and Smolen, 1990). This section describes monitoring methods that can be used to measure changes in pollutant loads and water quality. Due to the wide range of monitoring needs and environmental conditions throughout the coastal zone it is not possible to specify detailed monitoring plans that apply to all areas within the zone. The information in this section is intended merely to guide the development of monitoring efforts at the State and local levels.

This section begins with a brief discussion of the scope and nature of nonpoint source problems, followed by a discussion of monitoring objectives as they relate to section 6217. A lengthy discussion of monitoring approaches is next, with a focus on understanding the watershed to be studied, appropriate experimental designs, sample size and frequency, site locations, parameter selection, sampling methods, and quality assurance and quality control. The intent of this discussion is to provide the reader with basic information essential to the development of effective, tailored monitoring programs that will provide the necessary data for use in statistical tests that are appropriate for evaluating the success of management measures in reducing pollutant loads and improving water quality.

After a brief discussion of data needs, an overview of statistical considerations is presented. Variability and uncertainty are described first, followed by a lengthy overview of sampling and sampling designs. This discussion is at a greater level of detail than others in the section to emphasize the importance of adequate sampling within the framework of a sound experimental design. Hypothesis testing is described next, including some examples of hypotheses that may be appropriate for section 6217 monitoring efforts. An overview of data analysis techniques is given at the end of the section.

A. Nature and Scope of Nonpoint Source Problems

Nonpoint sources may generate both conventional and toxic pollutants, just as point sources do. Although nonpoint sources may contribute many of the same kinds of pollutants, these pollutants are generated in different volumes, combinations, and concentrations. Pollutants from nonpoint sources are mobilized primarily during storm events or snowmelt, but baseflow contributions can be the major source of nonpoint source contaminants in some systems. Thus, knowledge of the hydrology of a system is critical to the design of successful monitoring programs.

Nonpoint source problems are not just reflected in the chemistry of a water resource. Instead, nonpoint source problems are often more acutely manifested in the biology and habitat of the aquatic system. Such impacts include the destruction of spawning areas, impairments to the habitat for shellfish, changes to aquatic community structure, and fish mortality. Thus, any given nonpoint source monitoring program may have to include a combination of chemical, physical, and biological components to be effective.

B. Monitoring Objectives

Monitoring is usually performed in support of larger efforts such as nonpoint source pollution control programs within coastal watersheds. As such, monitoring objectives are generally established in a way that contributes toward achieving the broader program objectives. For example, program objectives may include restoring an impaired use or protecting or improving the ecological condition of a water resource. Supporting monitoring objectives, then, might include assessing trends in use support or in key biological parameters.

The following discussion identifies the overall monitoring objectives of section 6217 and gives some examples of specific objectives that may be developed at the State or local level in support of those overall objectives. Clearly, due to the prohibitive expense of monitoring the effectiveness of every management measure applied in the coastal zone, States will need to develop a strategy for using limited monitoring information to address the broad questions regarding the effectiveness of section 6217 implementation. A combination of watershed monitoring to track the cumulative benefits of systems of management measures and demonstrations of selected management measures of key importance in the State may be one way in which the overall section 6217 monitoring objectives can be met within the constraints imposed by limited State monitoring budgets.

1. Section 6217 Objectives

The overall management objective of section 6217 is to develop and implement management measures for nonpoint source pollution to restore and protect coastal waters. The principal monitoring objective under section 6217(g) is to assess over time the success of the management measures in reducing pollution loads and improving water quality. A careful reading of this monitoring objective reveals that there are two sub-objectives: (1) to assess changes in pollution loads over time and (2) to assess changes in water quality over time.

A pollutant load is determined by multiplying the total runoff volume times the average concentration of the pollutant in the runoff. Loads are typically estimated only for chemical and some physical (e.g., total suspended solids) parameters. Water quality, however, is determined on the basis of the chemical, physical, and biological conditions of the water resource. Section

6217(g), therefore, calls for a description of pollutant load estimation techniques for chemical and physical parameters, plus a description of techniques to assess water quality on the basis of chemical, physical, and biological conditions. This section focuses on those needs.

2. Formulating Monitoring Objectives

A monitoring objective should be narrowly and clearly defined to address a specific problem at an appropriate level of detail (Coffey and Smolen, 1990). Ideally, the monitoring objective specifies the primary parameter(s), location of monitoring (and perhaps the timing), the degree of causality or other relationship, and the anticipated result of the management action. The magnitude of the change may also be expressed in the objective. Example monitoring objectives include:

- To determine the change in trends in the total nitrogen concentration in Beautiful Sound due to the implementation of nutrient management on cropland in all tributary watersheds.
- To determine the sediment removal efficiency of an urban detention basin in New City.
- To evaluate the effects of improved marina management on metals loadings from the repair and maintenance areas of Stellar Marina.
- To assess the change in weekly mean total suspended solids concentrations due to forestry harvest activities in Clean River.

C. Monitoring Approaches

1. General

a. Types of Monitoring

The monitoring program design is the framework for sampling, data analysis, and the interpretation of results (Coffey and Smolen, 1990). MacDonald (1991) identifies seven types of monitoring:

1. Trend monitoring;
2. Baseline monitoring;
3. Implementation monitoring;
4. Effectiveness monitoring;
5. Project monitoring;
6. Validation monitoring; and
7. Compliance monitoring.

Trend, baseline, implementation, effectiveness, and project monitoring all relate to the monitoring objectives of section 6217. These types of monitoring, in fact, are not mutually exclusive. The distinction between effectiveness monitoring and project monitoring, for example, is often simply one of scale, with effectiveness monitoring primarily directed at individual practices and project monitoring directed at entire sets of practices or activities implemented over a larger area. Since one cannot evaluate the effectiveness of a project or

management measure (i.e., achievement of the desired effect) without knowing the status of implementation, implementation monitoring is an essential element of both project and effectiveness monitoring. In addition, a test for trend is typically included in the evaluation of projects and management measures, and baseline monitoring is performed prior to the implementation of pollution controls.

Meals (1991a) discussed five major points to consider in developing a monitoring system that would provide a suitable data base for watershed trend detection: (1) understand the system you want to monitor, (2) design the monitoring system to meet objectives, (3) pay attention to details at the beginning, (4) monitor source activities, and (5) build in feedback loops. These five points apply equally to both load estimation and water quality assessment monitoring efforts.

b. Section 6217 Monitoring Needs

The basic monitoring objective for section 6217 is to *assess over time the success of the measures in reducing pollution loads and improving water quality*. This objective would seem to indicate a need for establishing cause-effect relationships between management measure implementation and water quality. Although desirable, monitoring to establish such cause-effect relationships is typically beyond the scope of affordable program monitoring activities.

Mosteller and Tukey (1977) identified four criteria that must be met to show cause and effect: association, consistency, responsiveness, and a mechanism.

- **Association** is shown by demonstrating a relationship between two parameters (e.g., a correlation between the extent of management measure implementation and the level of pollutant loading).
- **Consistency** can be confirmed by observation only and implies that the association holds in different populations (e.g., management measures were implemented in several areas and pollutant loading was reduced, depending on the effect of treatment, in each case).
- **Responsiveness** can be confirmed by an experiment and is shown when the dependent variable (e.g., pollutant loading) changes predictably in response to changes in the independent variable (e.g., extent of management measure implementation).
- **Mechanism** is a plausible step-by-step explanation of the statistical relationship. For example, conservation tillage reduced the edge-of-field losses of sediment, thereby removing a known fraction of pollutant source from the stream or lake. The result was decreased suspended sediment concentration in the water column.

Clearly, the cost of monitoring needed to establish cause-effect relationships throughout the coastal zone far exceeds available resources. It may be suitable, however, to document associations between management measure implementation and trends in pollutant loads or water quality and then account for such associations with a general description of the primary mechanisms that are believed to come into play.

c. Scale, Local Conditions, and Variability

There are several approaches that can be taken to assess the effectiveness of measures in reducing loads and improving water quality. There are also several levels of scale that could be selected: individual practices, individual measures, field scale, watershed scale, basin scale, regional scale, etc. With any given monitoring objective, the specific monitoring approach to use at any specific site is a function of the local conditions (e.g., geography, climate, water resource type) and the type of management measures implemented.

The detection and estimation of trends is complicated by problems associated with the characteristics of pollution data (Gilbert, 1987). Physical, chemical, and biological parameters in the receiving water may undergo extreme changes without the influence of human activity. Understanding and monitoring the factors responsible for variability in a local system are essential for detecting the improvements expected from the implementation of management measures.

Simple point estimates taken before and after treatment will not confirm an effect if the natural variability is typically greater than the changes due to treatment (Coffey and Smolen, 1990). Therefore, knowledge of the variability and the distribution of the parameter is important for statistical testing. Greater variability requires a larger change to imply that the observed change is not due solely to random events (Spooner et al., 1987b). Examination of a historical data set can help to identify the magnitude of natural variability and possible sources.

The impact of management actions may not be detectable as a change in a mean value but rather as a change in variability (Coffey and Smolen, 1990). Platts and Nelson (1988) found that a carefully designed study was required to isolate the large natural fluctuations in trout populations to distinguish the effects of land use management. They assumed that normal fluctuation patterns were similar between the control and the treatment area and that treatment-induced effect could be distinguished as a deviation from the historical pattern.

Meals (1991a) calls for the collection and evaluation of existing data as the first step in a monitoring effort, recognizing that additional background data may be needed to identify hot spots or fill information gaps. The results of such initial efforts should include established stage-discharge ratings and an understanding of patterns not associated with the pollution control effort.

2. Understanding the System to Be Monitored

a. The Water Resource

Options for tracking water quality vary with the type of water resource. For example, a monitoring program for ephemeral streams can be different from that for perennial streams or large rivers. Lakes, wetlands, riparian zones, estuaries, and near-shore coastal waters all present different monitoring considerations. Whereas upstream-downstream designs work on rivers and streams, they are generally less effective on natural lakes where linear flow is not so prevalent. Likewise, estuaries present difficulties in monitoring loads because of the shifting flows and changing salinity caused by the tides. A successful monitoring program recognizes the unique features of the water resources involved and is structured to either adapt to those features or avoid them.

Streams. Freshwater streams can be classified on the basis of flow attributes as intermittent or perennial streams. Intermittent streams do not flow at all times and serve as conveyance systems for runoff. Perennial streams always flow and usually have significant inputs from ground water or interflow. For intermittent streams, seasonal variability is a very significant factor in determining pollutant loads and water quality. During some periods sampling may be impossible due to no flow. Seasonal flow variability in perennial streams can be caused by seasonal patterns in precipitation or snowmelt, reservoir discharges, or irrigation practices.

For many streams the greatest concentrations of suspended sediment and other pollutants occur during spring runoff or snowmelt periods. Concentrations of both particulate and soluble chemical parameters have been shown to vary throughout the course of a rainfall event in many studies across the Nation. This short-term variability should be considered in developing monitoring programs for flowing (lotic) waterbodies.

Spatial variability is largely lateral for both intermittent and perennial streams. Vertical variability does exist, however, and can be very important in both stream types (e.g., during runoff events, in tidal waters, and in deep, slow-moving streams). Intake depth is often a key factor in stream sampling. For example, slow-moving, larger streams may show considerable water quality variability with depth, particularly for parameters such as suspended solids, dissolved oxygen, and algal productivity. Suspended sediment samples must be taken with an understanding of the vertical distribution of both sediment concentration and flow velocity (Brakensiek et al., 1979). When sampling bed sediment or monitoring biological parameters, it is important to recognize the potential for significant lateral and vertical variation in the toxicity and contaminant levels of bed sediments (USEPA, 1987).

Lakes. Lakes can be categorized in several ways, but a useful grouping for monitoring guidance is related to the extent of vertical and lateral mixing of the waterbody. Therefore, lakes are considered to be either mixed or stratified for the purpose of this guidance. Mixed lakes are those lakes in which water quality (as determined by measurement of the parameters and attributes of interest) is homogenous throughout, and stratified lakes are considered to be those lakes which have lateral or vertical water quality differentials in the lake parameters and attributes of interest. Totally mixed lakes, if they exist, are certainly few in number, but it may be useful to perform monitoring in selected homogenous portions of stratified lakes to simplify data interpretation. Similarly, for lakes that exhibit significant seasonal mixing, it may be beneficial to monitor during a time period in which they are mixed. For some monitoring objectives, however, it may be best to monitor during periods of peak stratification.

Temporal variability concerns are similar for mixed and stratified lakes. Seasonal changes are often obvious, but should not be assumed to be similar for all lakes or even the same for different parts of any individual lake. Due to the importance of factors such as precipitation characteristics, climate, lake basin morphology, and hydraulic retention characteristics, seasonal variability should be at least qualitatively assessed before any lake monitoring program is initiated.

Short-term variability is also an inherent characteristic of most still (lentic) waterbodies. Parameters such as pH, dissolved oxygen, and temperature can vary considerably over the course

of a day. Monitoring programs targeted toward biological parameters should be structured to account for this short-term variability. It is often the case that small lakes and reservoirs respond rapidly to runoff events. This factor can be very important in cases where lake water quality will be correlated to land treatment activities or stream water quality.

In stratified lakes spatial variability can be lateral or vertical. The classic stratified lake is one in which there is an epilimnion and a hypolimnion (Wetzel, 1975). Water quality can vary considerably between the two strata, so sampling depth is an important consideration when monitoring vertically stratified lakes.

Lateral variability is probably as common as vertical variability, particularly in lakes and ponds receiving inflow of varying quality. Figure 8-1 illustrates the types of factors that contribute to lateral variability in lake water quality. In reservoir systems, storm plumes can cause significant lateral variability.

Davenport and Kelly (1984) explained the lateral variability in chlorophyll *a* concentrations in an Illinois lake based on water depth and the time period that phytoplankters spend in the photic zone. A horizontal gradient of sediment, nutrient, and chlorophyll *a* concentrations in St. Albans Bay, Vermont, was related to mixing between Lake Champlain and the Bay (Clausen, 1985). It is important to note that there frequently exists significant lateral and vertical variation in the toxicity and contaminant levels of bed sediments (USEPA, 1987).

Despite the distinction made between mixed and stratified lakes, there is considerable gray area between these groups. For example, thermally stratified lakes may be assumed to be mixed during periods of overturn, and laterally stratified lakes can sometimes be treated as if the different lateral segments are sub-lakes. In any case, it is important that the monitoring team knows what parcel of water is being sampled when the program is implemented. It would be inappropriate, for example, to assign the attributes of a surface sample to the hypolimnion of a stratified lake due to the differences in temperature and other parameters between the upper and lower waters.

Estuaries. Estuaries can be very complex systems, particularly large ones such as the Chesapeake Bay. Estuaries exhibit temporal and spatial variability just as streams and lakes do. Physically, the major differences between estuaries and fresh waterbodies are related to the mixing of fresh water with salt water and the influence of tides. These factors increase the complexity of spatial and temporal variability within an estuary.

Short-term variability in estuaries is related directly to the tidal cycles, which can have an effect on both the mixing of the fresh and saline waters and the position of the freshwater-saltwater interface (USEPA, 1982a). The same considerations made for lakes regarding short-term variability of parameters such as temperature, dissolved oxygen, and pH should also be made for estuaries.

Temperature profiles such as those found in stratified lakes can also change with season in estuaries. The resulting circulation dynamics must be considered when developing monitoring programs. The effects of season on the quantity of freshwater runoff to an estuary can be profound. In the Chesapeake Bay, for example, salinity is generally lower in the spring and

higher in the fall due to the changes in freshwater runoff from such sources as snowmelt runoff and rainfall (USEPA, 1982a).

Spatial variability in estuaries has both significant vertical and lateral components. The vertical variability is related to both temperature and chemical differentials. In the Chesapeake Bay thermal stratification occurs during the summer, and chemical stratification occurs at all times, but in different areas at different times (USEPA, 1982a). Chemical stratification can be the result of the saltwater wedge flowing into and under the freshwater outflow or the accumulation or channeling of freshwater and saltwater flows to opposite shores of the estuary. The latter situation can be caused by a combination of tributary location, the earth's rotation, and the barometric pressure. In addition, lateral variability in salinity can be caused by different levels of mixing between saltwater and freshwater inputs. As noted for streams and lakes, the lateral and vertical variation in the toxicity and contaminant levels of bed sediments should be considered (EPA, 1987).

Coastal Waters. Researchers and government agencies are collectively devoid of significant experience in evaluating the effectiveness of nonpoint source pollution control efforts through the monitoring of near-shore and offshore coastal waters. Our understanding of the factors to consider when performing such monitoring is therefore very limited.

As for other waterbody types, it is important to understand the hydrology, chemistry, and biology of the system in order to develop an effective monitoring program. Of particular importance is the ability to identify discrete populations to sample from. For trend analysis it is essential that the researcher is able to track over time the conditions of a clearly identifiable segment or unit of coastal water. This may be accomplished by monitoring a semi-enclosed near-shore embayment or similar system. Knowledge of salinity and circulation patterns should be useful in identifying such areas.

Secondly, monitoring should be focused on those segments or units of coastal water for which there is a reasonable likelihood that changes in water quality will result from the implementation of management measures. Segment size, circulation patterns, and freshwater inflows should be considered when estimating the chances for such water quality improvements.

Near-shore coastal waters may exhibit salinity gradients similar to those of estuaries due to the mixing of fresh water with salt water. Currents and circulation patterns can create temperature gradients as well. Farther from shore, salinity gradients are less likely, but gradients in temperature may occur. In addition, vertical gradients in temperature and light may be significant. These and other biological, chemical, and physical factors should be considered in the development of monitoring programs for coastal waters.

3. Experimental Design

a. Types of Experimental Designs

EPA has prescribed monitoring designs for use in watershed projects funded under section 319 of the Clean Water Act (USEPA, 1991b). The objective in promoting these designs is to document changes in water quality that can be related to the implementation of nonpoint source control measures in selected watersheds. The designs recommended by EPA are paired-

watershed designs and upstream-downstream designs. Single downstream station designs are not recommended by EPA for section 319 watershed projects (USEPA, 1991b).

Monitoring before implementation is usually required to detect a trend or show causality (Coffey and Smolen, 1990). Two years of pre-implementation monitoring are typically needed to establish an adequate baseline. Less time may be needed for studies at the management measure or edge-of-field scale, when hydrologic variability is known to be less than that of typical agricultural systems, or when a paired-watershed design is used.

Paired-Watershed Design. In the paired-watershed design there is one watershed where the level of implementation (ideally) does not change (the control watershed) and a second watershed where implementation occurs (the study watershed). This design has been shown in agricultural nonpoint source studies to be the most powerful study design for demonstrating the effectiveness of nonpoint source control practice implementation (Spooner et al., 1985). Paired-watershed designs have a long history of application in forest hydrology studies. The paired-watershed design must be implemented properly, however, to generate useful data sets. Some of the considerations to be made in designing and implementing paired-watershed studies are described below.

In selecting watershed pairs, the watersheds should be as similar as possible in size, shape, aspect, slope, elevation, soil type, climate, and vegetative cover (Striffler, 1965). The general procedure for paired-watershed studies is to monitor the watersheds long enough to establish a statistical relationship between them. A correlation should be found between the values of the monitored parameters for the two watersheds. For example, the total nitrogen values in the control watershed should be correlated with the total nitrogen values in the study watershed. A pair of watersheds may be considered sufficiently calibrated when a parameter for the control watershed can be used to predict the corresponding value for the study watershed (or vice versa) within an acceptable margin of error.

It is important to note that the calibration period should cover all or the significant portion of the range of conditions for each of the major water quality determinants in the two watersheds. For example, the full range of hydrologic conditions should be covered (or nearly covered) during the calibration period. This may be problematic in areas where rainfall and snowmelt are highly variable from year to year or in areas subject to extended wet periods or drought. Calibration during a dry year is likely to not be adequate for establishing the relationship between the two watersheds, particularly if subsequent years include both wet and dry periods. Similarly, some agricultural areas of the country use long-term, multiple-crop rotations. The calibration period should cover not only the range of hydrologic conditions but also the range of cropping patterns that can reasonably be expected to have an influence on the measured water quality parameters. This is not to say that the calibration period should take 5 to 10 years, but rather that States should use careful judgment in determining when the calibration period can be safely ended.

After calibration, the study watershed receives implementation of management measures, and monitoring is continued in both watersheds. The effects of the management measures are evaluated by testing for a change in the relationship between the monitored parameters (i.e., a

change in the correlation). If treatment is working, then there should be a greater difference over time between the treated study watershed and the untreated (poorly managed) control watershed. Alternatively, the calibration period could be used to establish statistical relationships between a fully treated watershed (control watershed) and an untreated watershed (study watershed). After calibration under this approach, the study watershed would be treated and monitoring continued. The effects of the management measures would be evaluated, however, by testing for a change in the correlation that would indicate that the two watersheds are more similar than before treatment.

It is important to use small watersheds when performing paired-watershed studies since they are more easily managed and more likely to be uniform (Striffler, 1965). EPA recommends that paired watersheds be no larger than 5,000 acres (USEPA, 1991b).

Upstream-Downstream Studies. In the upstream-downstream design, there is one station at a point directly upstream from the area where implementation of management measures will occur and a second station directly downstream from that area. Upstream-downstream designs are generally more useful for documenting the magnitude of a nonpoint source than for documenting the effectiveness of nonpoint source control measures (Spooner et al., 1985), but they have been used successfully for the latter. This design provides for the opportunity to account for covariates (e.g., an upstream pollutant concentration that is correlated with a downstream concentration of same pollutant) in statistical analyses and is therefore the design that EPA recommends in cases where paired watersheds cannot be established (USEPA, 1991b).

Upstream-downstream designs are needed in cases where project areas are not located in headwaters or where upstream activities that are expected to confound the analysis of downstream data occur. For example, the effects of upstream point source discharges, uncontrolled nonpoint source discharges, and upstream flow regulation can be isolated with upstream-downstream designs.

Inflow-Outflow Design. Inflow-outflow, or process, designs are very similar to upstream-downstream designs. The major differences are scale and the significance of confounding activities. Process designs are generally applied in studies of individual management measures or practices. For example, sediment loading at the inflow and outflow of a detention basin may be measured to determine the pollutant removal efficiency of the basin. In general, no inputs other than the inflow are present, and the only factor affecting outflow is the management measure. As noted above (see The Management Measures to Be Implemented), process monitoring cannot generally be applied to studies of source-reduction management measures or measures that prevent direct impacts, but it can be applied successfully in the evaluation of delivery-reduction management measures.

b. Scale

Management Measure. Monitoring the inflow and outflow of a specific management measure should be the most sensitive scale since the effects of uncontrollable discharges and uncertainties in treatment mechanisms are minimized.

Edge of Field. Monitoring pollutant load from a single-field watershed should be the next most sensitive scale since the direct effects of implementation can be detected without pollutant trapping in a field border or stream channel (Coffey and Smolen, 1990).

Sub-watershed. Monitoring a sub-watershed can be useful to monitor the aggregate effect of implementation on a group of fields or smaller areas by taking samples close to the treatment (Coffey and Smolen, 1990). Sub-watershed monitoring networks measure the aggregate effects of treatment and nontreatment runoff as it enters an upgradient tributary or the receiving waterbody. Sub-watershed monitoring can also be used for targeting critical areas.

Watershed. Monitoring at the watershed scale is appropriate for assessing total project area pollutant load using a single station (Coffey and Smolen, 1990). Depending on station arrangement, both sub-watershed and watershed outlet studies are very useful for water and pollutant budget determinations. Monitoring at the watershed outlet is the least sensitive of the spatial scales for detecting treatment effect. Sensitivity of the monitoring program decreases with increased basin size and decreased treatment extent or both (Coffey and Smolen, 1990).

c. Reference Systems and Standards

EPA's rapid bioassessment protocols advocate an integrated assessment, comparing habitat and biological measures with empirically defined reference conditions (Plafkin et al., 1989). Reference conditions are established through systematic monitoring of actual sites that represent the natural range of variation in "least disturbed" water chemistry, habitat, and biological condition. Reference sites can be used in monitoring programs to establish reasonable expectations for biological, chemistry, and habitat conditions. An example application of this concept is the paired-watershed design (Coffey and Smolen, 1990).

EPA's ecoregional framework can be used to establish a logical basis for characterizing ranges of ecosystem conditions or quality that are realistically attainable (Omernik and Gallant, 1986). *Ecoregions* are defined by EPA to be regions of relative homogeneity in ecological systems or in relationships between organisms and their environments. Hughes et al. (1986) have used a relatively small number of minimally impacted regional reference sites to assess feasible but protective biological goals for an entire region.

Water quality standards can be used to identify criteria that serve as reference values for biological, chemical, or habitat parameters, depending on the content of the standard. The frequency distribution of observation values can be tracked against either a water quality standard criterion or a reference value as a method for measuring trends in water quality or loads (USEPA, 1991b).

4. Site Locations

Within any given budget, site location is a function of water resource type (see The Water Resource), monitoring objectives (see Monitoring Objectives), experimental design (see Types of Experimental Designs), the parameters to be monitored (see Parameter Selection), sampling techniques (see Sampling Techniques and Samples and Sampling), and data analysis plans (see Data Analysis). Additional considerations in site selection are accessibility and landowner cooperation.

It is recommended that monitoring stations be placed near established gauging stations whenever possible due to the extreme importance of obtaining accurate discharge measurements. Where gauging stations are not available but stream discharge measurements are needed, care should be taken to select a suitable site. Brakensiek et al. (1979) provide excellent guidance regarding runoff measurement, including the following selected recommendations regarding site selection:

- Field-calibrated gauging stations should be located in straight, uniform reaches of channel having smooth beds and banks of a permanent nature whenever possible.
- Gauging stations should be located away from sewage outfall, power stations, or other installations causing flow disturbances.
- Consider the geology and contributions of ground-water flow.
- Where ice is a potential problem, locate measuring devices in a protected area that receives sunlight most of the time.
- Daily current-meter measurements may be necessary where sand shifts occur.

5. Sampling Frequency and Interval

a. Sample Size and Frequency

It is important to estimate early in a monitoring effort the number and frequency of samples required to meet the monitoring objectives. Spooner et al. (1991) report that the sampling frequency required at a given monitoring station is a function of the following:

- Monitoring goals;
- Response of the water resource to changes in pollutant sources;
- Magnitude of the minimum amount of change for which detection with trend analyses is desired (i.e., minimum detectable change);
- System variability and accuracy of the sample estimate of reported statistical parameter (e.g., confidence interval width on a mean or trend estimate);
- Statistical power (i.e., probability of detecting a true trend);
- Autocorrelation (i.e., the extent to which data points taken over time are correlated);
- Monitoring record length;
- Number of monitoring stations; and
- Statistical methods used to analyze the data.

The minimum detectable change (MDC) is the minimum change in a water quality parameter over time that is considered statistically significant. Knowledge of the MDC can be very useful in the planning of an effective monitoring program (Coffey and Smolen, 1990). The MDC can be

estimated from historical records to aid in determining the required sampling frequency and to evaluate monitoring feasibility (Spooner et al., 1987a). MacDonald (1991) discusses the same concept, referring to it as the minimum detectable effect.

The larger the MDC, the greater the change in water quality that is needed to ensure that the change was not just a random fluctuation. The MDC may be reduced by accounting for covariates, increasing the number of samples per year, and increasing the number of years of monitoring. Sherwani and Moreau (1975) stated that the desired frequency of sampling is a function of several considerations associated with the system to be studied, including:

- Response time of the system;
- Expected variability of the parameter;
- Half-life and response time of constituents;
- Seasonal fluctuation and random effects;
- Representativeness under different conditions of flow;
- Short-term pollution events;
- Magnitude of response; and
- Variability of the inputs.

Coastal waters, estuaries, ground water, and lakes will typically have longer response times than streams and rivers. Thus, sampling frequency will usually be greater for streams and rivers than for other water resource types. Some parameters such as total suspended solids and fecal coliform bacteria can be highly variable in stream systems dominated by nonpoint sources, while nitrate levels may be less volatile in systems driven by baseflow from ground water. The highly variable parameters would generally require more frequent sampling, but parameter variability should be evaluated on a site-specific basis rather than by rule of thumb.

In cases where pollution events are relatively brief, sampling periods may also be short. For example, to determine pollutant loads it may be necessary to sample frequently during a few major storm events and infrequently during baseflow conditions. Some parameters vary considerably with season, particularly in watersheds impacted primarily by nonpoint sources. Boating is typically a seasonal activity in northern climates, so intensive seasonal monitoring may be needed to evaluate the effectiveness of management measures for marinas.

The water quality response to implementation of management measures will vary considerably across the coastal zone. Pollutant loads from confined livestock operations may decline significantly in response to major improvements in runoff and nutrient management, while sediment delivery from logging areas may decline only a little if the level of pollution control prior to section 6217 implementation was already fairly good. Fewer samples will usually be needed to document water quality improvement in watersheds that are more responsive to pollution control efforts.

Sherwani and Moreau (1975) state that for a given confidence level and margin of error, the necessary sample size, and hence sampling frequency, is proportional to the variance. Since the variance of water quality parameters may differ considerably over time, the frequency requirements of a monitoring program may vary depending on the time of the year. Sampling frequency will need to be greater during periods of greater variance.

There are statistical methods for estimating the number of samples required to achieve a desired level of precision in random sampling (Cochran, 1963), stratified random sampling (Reckhow, 1979), cluster sampling (Cochran, 1977), multistage sampling (Gilbert, 1987), double sampling (Gilbert, 1987), and systematic sampling (Gilbert, 1987). For a more detailed discussion of sampling theory and statistics, see *Samples and Sampling*.

b. Sampling Interval

A method for estimating sampling interval is provided by Sherwani and Moreau (1975). They note that the least favorable sampling interval for parameters that exhibit a periodic structure is equal to the period or an integral multiple of the period. Such sampling would introduce statistical bias. Reckhow (1979) points out that, for both random and stratified random sampling, systematic sampling is acceptable only if "there is no bias introduced by incomplete design, and if there is no periodic variation in the characteristic measured." Gaugush (1986) states that monthly sampling is usually adequate to detect the annual pattern of changes with time.

c. Some Recommendations

It is generally recommended that the sampling of plankton, fish, and benthic organisms in estuaries should be seasonal, with the same season sampled in multiyear studies (USEPA, 1991a). The aerial coverage and bed density for submerged aquatic vegetation (SAV) vary from year to year due to catastrophic storms, exceptionally high precipitation and turbidity, and other poorly understood natural phenomena (USEPA, 1991a). For this reason, short-term SAV monitoring may be more reflective of infrequent impacts and may not be useful for trend assessment. In addition, incremental losses in wetland acreage are now within the margin of error for current detection limits. It is recommended that SAV and wetland sampling be conducted during the period of peak biomass (USEPA, 1991a).

The frequency of sediment sampling in estuaries should be related to the expected rate of change in sediment contaminant concentrations (USEPA, 1991a). Because tidal and seasonal variability in the distribution and magnitude of several water column physical characteristics in estuaries is typically observed, these influences should be accounted for in the development of sampling strategies (USEPA, 1991a).

For monitoring the state of biological variables, the length of the life cycle may determine the sampling interval (Coffey and Smolen, 1990). EPA (1991b) recommends a minimum of 20 evenly spaced (e.g., weekly) samples per year to document trends in chemical constituents in watershed studies lasting 5 to 10 years. The 20 samples should be taken during the time period (e.g., season) when the benefits of implemented pollution control measures are most likely to be observed. For benthic macroinvertebrates and fish, EPA recommends at least one sample per year.

8. Sampling Techniques

a. Automated Sampling to Estimate Pollutant Loads

Typical methods for estimating pollutant loads include continuous flow measurements and some form of automated sampling that is either timed or triggered by some feature of the runoff hydrograph. For example, in the Santa Clara watershed of San Francisco Bay, flow was continuously monitored at hourly intervals, wet-weather monitoring included collection of flow-composite samples taken with automatic samplers, and dry-weather monitoring was conducted by obtaining quarterly grab samples (Mumley, 1991). Data were used to estimate annual, wet-weather, and dry-weather copper loads.

In St. Albans Bay, Vermont, continuous flow and composite samples were used to estimate nutrient loads for trend analysis (Vermont RCWP, 1984). In the Nationwide Urban Runoff Program (NURP) project in Bellevue, Washington, catchment area monitoring included continuous gauging and automatic sampling that occurred at a preset time interval (5 to 50 minutes) once the stage exceeded a preset threshold (USEPA, 1982b).

b. Grab Sampling for Pollutant Loads

Grab sampling with continuous discharge gauging can be used to estimate load in some cases. Grab sampling is usually much less expensive than automated sampling methods and is typically much simpler to manage. These significant factors of cost and ease make grab sampling an attractive alternative to automated sampling and therefore worthy of consideration even for monitoring programs with the objective of estimating pollutant loads.

Grab sampling should be carefully evaluated to determine its applicability for each monitoring situation (Coffey and Smolen, 1990). Nonpoint source pollutant concentrations generally increase with discharge. For a system with potentially lower variability in discharge, such as irrigation, grab sampling may be a suitable sampling method for estimating loads (Coffey and Smolen, 1990). Grab sampling may also be appropriate for systems in which the distribution of annual loading occurs over an extended period of several months, rather than a few events. In addition, grab sampling may be used to monitor low flows and background concentrations.

For systems exhibiting high variability in discharge or where the majority of the pollutant load is transported by a few events (such as snowmelt in some northern temperate regions), however, grab sampling is not recommended.

c. Habitat Sampling

EPA recommends a procedure for assessing habitat quality where all of the habitat parameters are related to overall aquatic life use support and are a potential source of limitation to the aquatic biota (Plafkin et al., 1989). In this procedure, EPA begins with a survey of physical characteristics and water quality at the site. Such physical factors as land use, erosion, potential nonpoint sources, stream width, stream depth, stream velocity, channelization, and canopy cover are addressed. In addition, water quality parameters such as temperature, dissolved oxygen, pH, conductivity, stream type, odors, and turbidity are observed.

Then, EPA follows with the habitat assessment, which includes a range of parameters that are weighted to emphasize the most biologically significant parameters (Plafkin et al., 1989). The procedure includes three levels of habitat parameters. The primary parameters are those that

characterize the stream "microscale" habitat and have the greatest direct influence on the structure of the indigenous communities. These parameters include characterization of the bottom substrate and available cover, estimation of embeddedness, and estimation of the flow or velocity and depth regime. Secondary parameters measure the "macroscale" and include such parameters as channel alteration, bottom scouring and deposition, and stream sinuosity. Tertiary parameters include bank stability, bank vegetation, and streamside cover.

MacDonald (1991) discusses a wide range of channel characteristics and riparian parameters that can be monitored to evaluate the effects of forestry activities on streams in the Pacific Northwest and Alaska. MacDonald states that "stream channel characteristics may be advantageous for monitoring because their temporal variability is relatively low, and direct links can be made between observed changes and some key designated uses such as coldwater fisheries." He notes, however, that "general recommendations are difficult because relatively few studies have used channel characteristics as the primary parameters for monitoring management impacts on streams."

On the other hand, MacDonald concludes that the documented effects of management activities on the stability and vegetation of riparian zones, and the established linkages between the riparian zone and various designated uses, provide the rationale for including the width of riparian canopy opening and riparian vegetation as recommended monitoring parameters. Riparian canopy opening is measured and tracked through a historical sequence of aerial photographs (MacDonald, 1991). Riparian vegetation is measured using a range of methods, including qualitative measures of vegetation type, visual estimations of vegetation cover, quantitative estimations of vegetation cover using point- or line-intercept methods, light intensity measurements to estimate forest cover density, stream shading estimates using a spherical densiometer, and estimates of vegetation density based on plot measurements.

Habitat variables to monitor grazing impacts include areas covered with vegetation and bare soil, stream width, stream channel and streambank stability, and width and area of the riparian zone (Platts et al., 1987). Ray and Megahan (1978) developed a procedure for measuring streambank morphology, erosion, and deposition. Detailed streambank inventories may be recorded and mapped to monitor present conditions or changes in morphology through time.

To assess the effect of land use changes on streambank stability, Platts et al. (1987) provide methods for evaluating and rating streambank soil alteration. Their rating system can be used to determine the conditions of streambank stability that could affect fish. Other measurements that could be important for fisheries habitat evaluations include streambank undercut, stream shore water depth, and stream channel bank angle.

d. Benthic Organism Sampling

Benthic communities in estuaries are sampled through field surveys, which are typically time-consuming and expensive (USEPA, 1991a). Sampling devices include trawls, dredges, grabs, and box corers. For more specific benthic sampling guidance, see Klemm et al. (1990).

e. Fish Sampling

For estuaries and coastal waters, a survey vessel manned by an experienced crew and specially equipped with gear to collect organisms is required (USEPA, 1991a). Several types of devices and methods can be used to collect fish samples, including traps and cages, passive nets, trawls (active nets), and photographic surveys. Since many of these devices selectively sample specific types of fish, it is not recommended that comparisons be made among data collected using different devices (USEPA, 1991a).

f. Shellfish Sampling

Pathobiological methods provide information concerning damage to organ systems of fish and shellfish through an evaluation of their altered structure, activity, and function (USEPA, 1991a). A field survey is required to collect target organisms, and numerous tissue samples may be required for pathobiological methods. In general, pathobiological methods are labor-intensive and expensive (USEPA, 1991a).

g. Plankton Sampling

Phytoplankton sampling in coastal waters is frequently accomplished with water bottles placed at a variety of depths throughout the water column, some above and some below the pycnocline (USEPA, 1991a). A minimum of four depths should be sampled. Zooplankton sampling methods vary depending on the size of the organisms. Devices used include water bottles, small mesh nets, and pumps (USEPA, 1991a).

h. Aquatic Vegetation Sampling

Attributes of emergent wetland vegetation can be monitored at regular intervals along a transect (USEPA, 1991a). Measurements include plant and mulch biomass, and foliar and basal cover. Losses of aquatic vegetation can be tracked through aerial photography and mapping.

i. Water Column Sampling

In estuaries and coastal waters, chemical samples are frequently collected using water bottles and should be taken at a minimum of four depths in the vertical profile (USEPA, 1991a). Caged organisms have also been used to monitor the bioaccumulation of toxic chemicals.

Physical sampling of the water column at selected depths in estuaries is done with bottles for temperature, salinity, and turbidity, or with probes for temperature and salinity (USEPA, 1991a). Current meters are used to characterize circulation patterns.

j. Sediment Sampling

Several types of devices can be used to collect sediment samples, including dredges, grabs, and box corers (USEPA, 1991a). Sampling depth may vary depending on the monitoring objective, but it is recommended that penetration be well below the desired sampling depth to prevent sample disturbance as the device closes (USEPA, 1991a). EPA also recommends the selection of sediment samplers that also sample benthic organisms to cut sampling costs and to permit better statistical analyses relating sediment quality to benthic organism parameters.

k. Bacterial and Viral Pathogen Sampling

For estuaries and coastal waters it is recommended that samples be taken of both the underlying waters and the thin microlayer on the surface of the water (USEPA, 1991a). This is recommended, despite the fact that standardized methods for sampling the microlayer have not been established, because research has shown bacterial levels several orders of magnitude greater in the microlayer. In no case should a composite sample be collected for bacteriological examination (USEPA, 1978).

Water samples for bacterial analyses are frequently collected using sterilized plastic bags or screw cap, wide-mouthed bottles (USEPA, 1991a). Several depths may be sampled during one cast, or replicate samples may be collected at a particular depth by using a Kemmerer or Niskin sampler (USEPA, 1978). Any device that collects water samples in unsterilized tubes should not be used for collecting bacteriological samples without first obtaining data that support its use (USEPA, 1991a). Pumps may be used to sample large volumes of the water column (USEPA, 1978).

9. Quality Assurance and Quality Control

Effective quality assurance and quality control (QA/QC) procedures and a clear delineation of QA/QC responsibilities are essential to ensure the utility of environmental monitoring data (Plafkin et al., 1989). Quality control refers to the routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurement process. Quality assurance includes the quality control functions and involves a totally integrated program for ensuring the reliability of monitoring and measurement data.

EPA's QA/QC program requires that all EPA National Program Offices, EPA Regional Offices, and EPA laboratories participate in a centrally planned, directed, and coordinated Agency-wide QA/QC program (Brossman, 1988). This requirement also applies to efforts carried out by the States and interstate agencies that are supported by EPA through grants, contracts, or other formalized agreements. The EPA QA program is based on EPA order 5360.1, which describes the policy, objectives, and responsibilities of all EPA Program and Regional Offices (USEPA, 1984).

Each office or laboratory that generates data under EPA's QA/QC program must implement, at a minimum, the prescribed procedures to ensure that precision, accuracy, completeness, comparability, and representativeness of data are known and documented. In addition, EPA QA/QC procedures apply throughout the study design, sample collection, sample custody, laboratory analysis, data review (including data editing and storage), and data analysis and reporting phases.

Specific guidance for QA/QC is provided for EPA's rapid bioassessment protocols (Plafkin et al., 1989) and for EPA's Ocean Data Evaluation System (USEPA, 1991a). Standardized procedures for field sampling and laboratory methods are an essential element of any monitoring program.

D. Data Needs

Data needs are a direct function of monitoring goals and objectives. Thus, data needs cannot be established until specific goals and objectives are defined. Furthermore, data analyses should be planned before data types and data collection protocols are agreed upon. In short, the scientific

method, defined as "a method of research in which a problem is identified, relevant data gathered, an hypothesis formulated, and the hypothesis empirically tested" (Stein, 1980), should be applied to determine data needs. Types of data generally needed for nonpoint source monitoring programs will include chemical, physical, and biological water quality data; precipitation data; topographic and morphologic data; soils data; land use data; and land treatment data. The specific parameters should be determined based on site-specific needs and the monitoring objectives that are established.

Under EPA's quality assurance and quality control (QA/QC) program (see Quality Assurance and Quality Control), a full assessment of the data quality needed to meet the intended use must be made prior to specification of QA/QC controls (Brossman, 1988). The determination of data quality is accomplished through the development of data quality objectives (DQOs), which are qualitative and quantitative statements developed by data users to specify the quality of data needed to support specific decisions or regulatory actions. Establishment of DQOs involves interaction of decision makers and the technical staff. EPA has defined a process for developing DQOs (USEPA, 1986).

Appendix 12

Example Site Location Form **(courtesy of Alliance for the Chesapeake Bay)**



Office Use Only
Monitoring Coordinator: _____
Site Designation: _____
Tributary: _____
Date Site Information entered into database: _____

ACB Citizen Monitoring Site Documentation

Instructions: Please fill in this form as fully and accurately as possible. The information you provide will be used to document monitoring site locations. Be as descriptive as you can. We need to have precise site documentation to enable the location of your site in the future. In each of the Sections, circle the option that applies.

SITE NAME: _____
 PRIMARY MONITOR'S NAME: _____
 BACK-UP MONITOR'S NAME: _____
 DATA COLLECTION START DATE: _____

I. Location Description: (Please Circle)

Tidal Nontidal Lake
 Water body (What Creek, Stream, River, Lake the site is on)

Other Location _____

Details: _____

II. Collection Description: (Please Circle)

Shoreline Pier/Dock Bridge crossing
 Boat Wading to Stream Center

III. Coordinates:

*A USGS 7-minute quadrangle map or a GPS Unit are the recommended methods for determining site coordinates. You can find all USGS quadrangle maps online for free by going to www.topozone.com. You may search by place name or by river name by choosing the link titled "Place Name Search" under "Get A Map". Once you have located your site, you may zoom in by clicking on the 1:25,000 button in the top left corner above the map. Use your mouse to click on the exact location- a red crosshair will appear over your site. Choose "DD.DDDD" (decimal degrees) as the coordinate type located beneath the map. The coordinates will then be listed in these units above the map. You can then either print the map, or email it to us. You can also find USGS maps for local areas at libraries, fishing and camping stores, and engineering and architectural supply stores. Cost is about \$3.00 a map.

Please Put in Units in Decimal Degrees (DD.DDDD)

LATITUDE: _____ **LONGITUDE:** _____
 (Example: 37.1234) (Example: -77.1234)

- ☐ MAP- Please attach a map of your site to this form, with the site labeled.*
 - ☐ PHOTO DOCUMENTATION- It is recommended that you visually document your site with photographs of the monitoring location looking upstream and downstream. Label the photos accordingly, and attach copies to this form.
- (Updated 11/18/02)

Appendix 13

Handout from Virginia Water Monitoring Council's Quality Assurance/Quality Control Forum

Basic QA/QC Concepts

Modified from *The Volunteer Monitor's Guide to Quality Assurance Project Plans*. EPA 841-B-96-003. September 1996. This guide is recommended for all citizen monitoring organizations in Virginia interested in developing a quality assurance project plan. The guide is available online at www.epa.gov/owow/monitoring/volunteer/.

Quality Assurance (QA)

Refers to a broad plan for maintaining quality in all aspects of a program, including all quality control measures, sample collection, sample analysis, data management, documentation, evaluation, *etc.* It is helpful to data users in determining the integrity (soundness) of data.

Quality Control (QC)

The steps, including measurements, calibrations, and standardization practices, taken to assure the quality of specific sampling and analytical procedures. QC is used to reduce error in the data collection and analysis. For example, the collection of two samples (QC samples) taken at the same time and location should yield the same (or very similar) results; data quality can be determined by evaluating the results of the QC samples and determining precision and accuracy. The decision to accept data, reject it, or accept only a portion of it should be made after analysis of the QC data.

Quality Assurance Project Plan (QAPP)

The formal written document describing the detailed quality assurance procedures and QC activities that will be used to assure data quality.

Precision

Degree of agreement among repeated measurements. Reproducible results are precise. Can be calculated using the standard deviation (a statistical way to measure variation around the data set's average value).

Accuracy

Measures how close your results are to a *true* value. The smaller the difference between the measurement and its "true" value, the more accurate the measurement. Found by analyzing a standard or reference sample (one with a known value).

Representativeness

The extent to which measurements actually depict the true condition being evaluated. For example, data collected just below a pipe outfall are not representative of the entire stream.

Completeness

The number of samples and documentation needed to meet the sampling objectives. Volunteers may not be able to collect as many samples as planned so try to take more samples than you expect to need.

Comparability

The extent to which data from one study can be directly compared to either past data obtained in the study or from data obtained in another study.

Detection Limit

In general, the lowest concentration of a given parameter your method or equipment can reliably detect and report as greater than zero. For example, if an instrument has a detection limit of 1 ppb (parts per billion) and a sample contains 0.5 ppb of lead, the sample will be “below the detection limit.” Note, this does not mean the sample is free of lead (0 ppb), simply that the amount of lead is less than the instrument can detect.

Metadata

Metadata is data about the data. It describes the data information presented in a given dataset and quality criteria associated with their generation. Metadata is all other data collected that is not the actual value of the parameter measured. Metadata provides information on the procedures used, quality control measures, site locations, sample collectors, quality of the data, etc.

Standard Operating Procedures (SOPs)

Written instructions, which describe the step-by-step procedures for a process. For example, the procedures for collecting a water sample are referred to as field SOPs while the procedures for analyzing the sample in a lab are referred to as the lab SOPs.

Information provided by the **Virginia Water Monitoring Council (VWMC)**. To join the VWMC, contact **Jane Walker** at **540-231-4159** or vwmc@vt.edu. A special thank you to DEQ for assistance with this handout.



Appendix 14

Quality Assurance Project Plan Template

This quality assurance project plan template (from EPA 1996, *The Volunteers Monitor's Guide to Quality Assurance Project Plans*) can be used as you develop your Quality Assurance Project Plan for the Department of Environmental Quality DEQ). Please consult other data users to determine if use of this form (or a modified version) is acceptable to them.

1. Title and Approval Page

<div style="text-align: center; margin-bottom: 10px;"> <hr style="width: 80%; margin: 0 auto;"/> (Project Name) </div> <div style="text-align: center; margin-bottom: 10px;"> <hr style="width: 80%; margin: 0 auto;"/> (Responsible Agency) </div> <div style="text-align: center;"> <hr style="width: 80%; margin: 0 auto;"/> (Date) </div>
<div style="border: 1px solid black; padding: 2px;">Project Manager Signature</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Name/Date</div>
<div style="border: 1px solid black; padding: 2px;">Project QA Officer Signature</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Name/Date</div>
<div style="border: 1px solid black; padding: 2px;">USEPA Project Manager Signature</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Name/Date</div>
<div style="border: 1px solid black; padding: 2px;">USEPA QA Officer Signature</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Name/Date</div>

2. Table of Contents

List sections with page numbers, figures, tables, references, and appendices (attach pages).

3. Distribution List

Names and telephone numbers of those receiving copies of this QAPP. Attach additional page, if necessary.

i.	_____
ii.	_____
iii.	_____
iv.	_____
v.	_____
vi.	_____
vii.	_____
viii.	_____
ix.	_____
x.	_____

4. Project/Task Organization

List key project personnel and their corresponding responsibilities.

Name	Project Title/Responsibility
	Advisory Panel (contact)
	Project Manager
	QA Officer
	Field/Sampling Leader
	Laboratory Manager/Leader

5. Problem Definition/Background

A. Problem Statement

B. Intended Usage of Data

6. Project/Task Description

A. General Overview of Project

C. Project Timetable

Activity	Projected Start Date	Anticipated Date of Completion

8. Measurement Quality Objectives

A. Data Precision, Accuracy, Measurement Range

Matrix	Parameter	Measurement Range	Accuracy	Precision

B. Data Representativeness

C. Data Comparability

D. Data Completeness

Parameter	No. Valid Samples Anticipated	No. Valid Samples Collected & Analyzed	Percent Complete

8. Training Requirements and Certification

A. Training Logistical Arrangements

Type of Volunteer Training	Frequency of Training/Certification

B. Description of Training and Trainer Qualifications

9. Documentation and Records

10. Sampling Process Design

A. Rationale for Selection of Sampling Sites

B. Sample Design Logistics

	Type of Sample/ Parameter	Number of Samples	Sampling Frequency	Sampling Period
Biological				
Physical				
Chemical				

11. Sampling Method Requirements

Parameter	Sampling Equipment	Sampling Method

12. Sample Handling and Custody Procedures

13. Analytical Methods Requirements

14. Quality Control Requirements

A. Field QC Checks

B. Laboratory QC Checks

C. Data Analysis QC Checks

15. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Equipment Type	Inspection Frequency	Type of Inspection

16. Instrument Calibration and Frequency

Equipment Type	Calibration Frequency	Standard or Calibration Instrument Used

17. Inspection/Acceptance Requirements

18. Data Acquisition Requirements

19. Data Management

20. Assessment and Response Actions

21. Reports

21. Data Review, Validation, and Verification

22. Validation and Verification Methods

23. Reconciliation with DQO=s

Appendix 15

Determining the Expiration Date of Some Commonly Used Reagents

(courtesy of Alliance for the Chesapeake Bay)

Determining the Expiration Date of Some Commonly Used Reagents

This Appendix is used by the Alliance for the Chesapeake Bay to determine the expiration date of the reagents used by organizations using the Alliance's protocols (LaMotte Dissolved Oxygen and pH test kits).

How to determine "expiration date" of chemicals:

Assuming that chemicals have been stored properly (cool, dark place- not exposed to long periods of sunlight or heat), the chemicals, even once opened should be good for as long as the shelf life indicated in Table 1.

Table 1

Chemicals	Shelf Life (years)
Manganese Sulfate	3
Alkaline Azide	3
Starch	18 months
Sulfuric Acid (and powder)	2
Sodium Thiosulfate	1
Chlorophenol Red	2
Phenol red	2
Cresol Red	2
Wide Range indicator	2
Bromcresol	2
Thymol Blue	2
Bromthymol Blue	2
LaMotte Yellow	2

To determine the date that your chemicals were made, look at the first 3 digits in the lot number listed on your chemical label.

Example:

Chemical- sulfuric acid
Lot No. 1002345

The first 2 digits indicate the week of the year in which the chemicals were made. The 3rd digit indicated the year in which the chemicals were made. So this bottle of sulfuric acid was made in the 10th week of 2000. Based on the table above, this chemical should be good until the 10th week of 2002, or the beginning of March 2002, using the calendar for 2001.

Appendix 16

Dissolved Oxygen Saturation Concentrations

Dissolved Oxygen Saturation Concentrations

Example: If your water temperature at a freshwater site is 5.1 °C, the potential dissolved oxygen (DO) level (highest DO concentration possible) is 12.71 mg/l. See the next page for compensating for barometric pressure. If the barometric pressure in this example is 760 mm Hg, then your correction factor is 1.00, which makes the potential DO 13.71 mg/l.

Temp in °C	O ₂ concentrations in mg/l									
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	12.75	12.71	12.68	12.65	12.61	12.58	12.55	12.52	12.48	12.45
6	12.42	12.39	12.36	12.32	12.29	12.26	12.23	12.20	12.17	12.14
7	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.90	11.87	11.84
8	11.81	11.78	11.758	11.72	11.69	11.67	11.64	11.61	11.58	11.55
9	11.53	11.50	11.47	11.44	11.42	11.39	11.36	11.33	11.31	11.28
10	11.25	11.23	11.20	11.18	11.15	11.12	11.10	11.07	11.05	11.02
11	10.99	10.97	10.94	10.92	10.89	10.87	10.84	10.82	10.79	10.77
12	10.75	10.72	10.70	10.67	10.65	10.63	10.60	10.58	10.55	10.53
13	10.51	10.48	10.46	10.44	10.41	10.39	10.37	10.35	10.32	10.30
14	10.28	10.26	10.23	10.21	10.19	10.17	10.15	10.12	10.10	10.08
15	10.06	10.04	10.02	9.99	9.97	9.95	9.93	9.91	9.89	9.87
16	9.85	9.83	9.81	9.79	9.76	9.74	9.72	9.70	9.68	9.66
17	9.64	9.62	9.60	9.58	9.56	9.54	9.53	9.51	9.49	9.47
18	9.45	9.43	9.41	9.39	9.37	9.35	9.33	9.31	9.30	9.28
19	9.26	9.24	9.22	9.20	9.19	9.17	9.15	9.13	9.11	9.09
20	9.08	9.06	9.04	9.02	9.01	8.99	8.97	8.95	8.94	8.92
21	8.90	8.88	8.87	8.85	8.83	8.82	8.80	8.78	8.76	8.75
22	8.73	8.71	8.70	8.68	8.66	8.65	8.63	8.62	8.60	8.58
23	8.57	8.55	8.53	8.52	8.50	8.49	8.47	8.46	8.44	8.42
24	8.41	8.39	8.38	8.36	8.35	8.33	8.32	8.30	8.28	8.27
25	8.25	8.24	8.22	8.21	8.19	8.18	8.16	8.15	8.14	8.12
26	8.11	8.09	8.08	8.06	8.05	8.03	8.02	8.00	7.99	7.98
27	7.96	7.95	7.93	7.92	7.90	7.89	7.88	7.86	7.85	7.83
28	7.82	7.81	7.79	7.78	7.77	7.75	7.74	7.73	7.71	7.70
29	7.69	7.67	7.66	7.65	7.63	7.62	7.61	7.59	7.58	7.57
30	7.55	7.54	7.53	7.51	7.50	7.49	7.48	7.46	7.45	7.44

Barometric Pressure Corrections:

mm Hg.	Correction Factor	mm Hg.	Correction Factor	mm Hg	Correction Factor
760	1.00	735	0.967	710	0.934
755	0.993	730	0.96	705	0.927
750	0.987	725	0.953	700	0.92
745	0.98	720	0.947	695	0.914
740	0.973	715	0.94	690	0.907